

The Conceptualization of Space: The Case of Long Long Rak Cave, Pang Mapha, Mae Hong Son, Thailand

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Abstract

Caves often are used as metaphors for spaces of transformation—spaces that symbolize shifts in perspectives and understanding, moving from old frameworks to new ones. This transition frequently involves moving beyond material attachments toward a deeper comprehension of knowledge and intelligence (Tearle, 2023). In the architectural discipline, caves often are portrayed as abstract spaces, mysterious and complex, evoking curiosity and excitement (Bashir, 2013; Sukkarieh, 2013). However, in this article, the “caves” in question are not metaphorical but physical spaces specifically used to house coffins, as part of the “coffin culture” of tribes that have inhabited Pang Mapha District since prehistoric times. These “Coffin Caves” are well-defined areas with precise locations. Rather than focusing on expanding archaeological knowledge of Coffin Caves, this article delves into the conceptualization and spatial design of caves to reveal new perspectives on the relationship between the cave environment and the placement of wooden coffins. This exploration is particularly enriched when viewed through an architectural and spatial lens, supported by archaeological data. The article discusses the mechanisms and techniques employed to analyze and interpret these relationships, ranging from simple methods such as sketching and manual grid system recording to the application of advanced laser scanning technology with LiDAR. By integrating data sets related to the caves and the wooden coffin locations, the design team explored ways to adapt the cave spaces into a medium for learning and preserving the “wooden coffin culture” and the heritage of “Coffin Caves.”

Keywords

Spatial conceptualization in design; Coffin Cave; Long Long Rak; Pang Mapha; Space and cultural heritage; Laser scanning LiDAR

1. Introduction

This article is part of an interdisciplinary collaboration encompassing archaeology, anthropology, biology, science, physics, history, linguistics, art, and architecture within the “Conservation of Ancient Log Coffin of Phi Man Long Long Rak Cave, Mae Hong Son” project (Shoocongdej, 2021b). The research project, which has been ongoing for a considerable period, focuses on the study and preservation of “Wooden Coffin Culture” (Shoocongdej, 2020). Interdisciplinary integration has emerged as a prominent approach to acquiring new knowledge over the past decade. For some scholars, this is characteristic of the postmodern era, which challenges established knowledge systems, methods of inquiry, and assumptions deeply embedded within individual disciplines. This integration is not merely about combining expertise but about questioning traditional methodologies, probing the essence of knowledge, and fostering connections and critical dialogues among diverse fields. Such integration forms have become the foundation of this research team’s work, led by Professor Dr. Rasami Shoocongdej. This project involves four main working teams: (1) Archaeology Team consisting of Siriluck Kanthasri, Varis Domethong, Somthawin Sukleang, Chanchanok Samrit, and Wokanya Na Nongkhai; (2) Conservation Team consisting of Mrs. Puangporn Srisomboon, along with the Science for Conservation Group, the National Museum Division, Fine Arts Department, (3) Design Team consisting of Sant Suwatharapinun, Piyakan Kunthiya, Bupparatana Sirilaph, and Metaporn Apriratigosol, including 3D cave scanning technicians, Romchat ChooChote, Withawin Mahaumai, Nattaphol Mookthawat, and Piyawat Sangngoenchai; and (4) Community Building Team consisting of Siriluck Kanthasri and Varis Domethong. The project rejects rigid adherence to Western-centric frameworks and logic when explaining phenomena in the surveyed area. Instead, it emphasizes the importance of local factors and contexts, drawing comparisons with the cultural narratives of prehistoric communities whose traces still endure. Rasami encourages open exchanges of perspectives across disciplines and actively incorporates local wisdom from various communities in the region. This holistic approach has allowed the research team to reinterpret and expand the study of the “Wooden Coffin Culture” and the “Lacquered Coffin Cave” in Pang Mapha District, Mae Hong Son Province (Shoocongdej, 2020; Samrit & (R. Shoocongdej, personal communication, January 26, 2024). Buajan et al., 2020; Carlhoff et al., 2023). By integrating diverse bodies of knowledge, the project offers a unique lens to explore and understand these historically significant cave sites.

2. Background: Historical and Physical Context of the Wooden Coffin Culture and the Lacquered Coffin Cave

Before delving into the topic of “Creating a spatial concept of the cave in relation to the location of the wooden coffin,” it is essential to first introduce the concepts of the “Wooden Coffin Culture” and the “Lacquered Coffin Cave.” This provides a foundational understanding of the initial archaeological context and the scope of the research team’s work. A significant part of the project’s intrigue lies in exploring a cave area that has remained inaccessible to the public. Only a select few have had the rare opportunity to explore the depths of this hidden cave, nestled within a remote valley. For this reason, studying the Wooden Coffin Culture and the Lacquered Coffin Cave in Pang Mapha District, Mae Hong Son Province, is a unique and extraordinary experience.



Figure 1. Pictures inside the Lacquer Coffin Cave, Room
Source: Pictures from the design team (November 21, 2021)

The “Wooden Coffin Culture” represents a distinctive burial tradition that differs from contemporary practices involving soil burial or cremation. Instead, the deceased were placed in large wooden coffins and positioned in valleys, mountain crevices, or on steep cliffs. This culture, which emerged approximately 2,200 - 1,100 years ago (late Pleistocene to early Holocene), reflects the unique identity of highland communities. The burial sites predominantly are found in the mountainous regions of western Thailand, spanning Mae Hong Son to Chiang Mai, with a concentration in Pang Mapha District, Mae Hong Son Province, where numerous wooden coffins have been unearthed (Figure 1). Highland communities associated with this culture were semi-nomadic, moving seasonally in search of resources. Their settlements often were in caves or on cliffs that provided natural shelter from the elements. Their death rituals centered around burials rather than cremations, with locations chosen based on their symbolic and practical significance (Samrit & Shoocongdej, 2024; Shoocongdej, 2021a; Shoocongdej et al., 2019) . These communities typically inhabited limestone mountain ranges with steep cliffs and caves formed by natural erosion. For burial rituals, caves held special importance. Caves selected as burial sites often were on high mountaintops or steep cliffs, emphasizing the ritual’s significance and ensuring the sites were difficult to access (Shoocongdej et al., 2022; Phumichanong et al., 2022; Kanoksilapatham et al., 2022) . Most caves selected for burial were “dry caves” or “dead caves” having lesser geological activity to ensure preservation. In some cases, burial sites required descending into underground cavities with flat surfaces suitable for placing wooden coffins, such as those in the Long Rak Coffin Cave.

The term “Phi Man” or “Long Phi Man” is a local Shan term for a wooden coffin, meaning “emerging” (Shoocongdej, 2013; Carlhoff et al., 2023). Originally, wooden coffins were referred to simply as “Phi Man,” which is why the term “Long Mai” or “Phi Man” often appears together. Most wooden coffins found in the Pang Mapha Highlands were crafted from teak wood. Their age can be determined by analyzing the annual growth rings of the trees. The choice of teak reflects an intentional selection of materials that align with the surrounding environment. The Pang Mapha Highlands, characterized by a savannah forest climate with distinct wet and dry seasons, supports mixed deciduous and dry dipterocarp forests, providing a natural source of teak for coffin construction. These coffins are significant cultural artifacts central to the funeral rites and death rituals of the “wooden coffin culture.” The deceased were placed in teak coffins, often adorned with carved patterns at their ends. Inside the caves, the coffins were arranged systematically, with a single cave cavity

frequently serving as a family burial site (Shoocongdej et al., 2013; Buajan et al., 2020; Carlhoff et al., 2023). Coffins could contain the remains of more than one family member. When a coffin became full, the bones of earlier deceased individuals were removed and placed beside the coffin to make space for the body of a newly deceased family member. This process was accompanied by rituals to honor the deceased and preserve the continuity of the family’s burial tradition within the same wooden coffin (Samrit & Shoocongdej, 2024; (R. Shoocongdej, personal communication, January 26, 2024) .

The “Long Long Rak Cave” area underwent excavation between 2010 and 2021. This cave is situated amidst a bamboo forest on top of limestone cliffs at an elevation of 735 meters above sea level and approximately 300 meters from the Lang River. The cave’s name, “Long Long Rak,” refers to the wooden coffins coated with lacquer to preserve the wood, reflecting the wisdom of past generations. The cave is located 15 meters below its entrance and is divided into three main chambers: A, B, and C. In Chamber A, approximately 30 wooden coffins were discovered. This research focuses primarily on Chamber A, which contains numerous well-preserved wooden coffins. Archaeologists have clearly identified and mapped the locations of all 16 coffins within this chamber. Among the findings, nine distinct types of coffin head designs have been identified, offering valuable insights into the craftsmanship and cultural practices associated with the “wooden coffin culture” (Shoocongdej, 2020).

3. Research Methodology and Framework

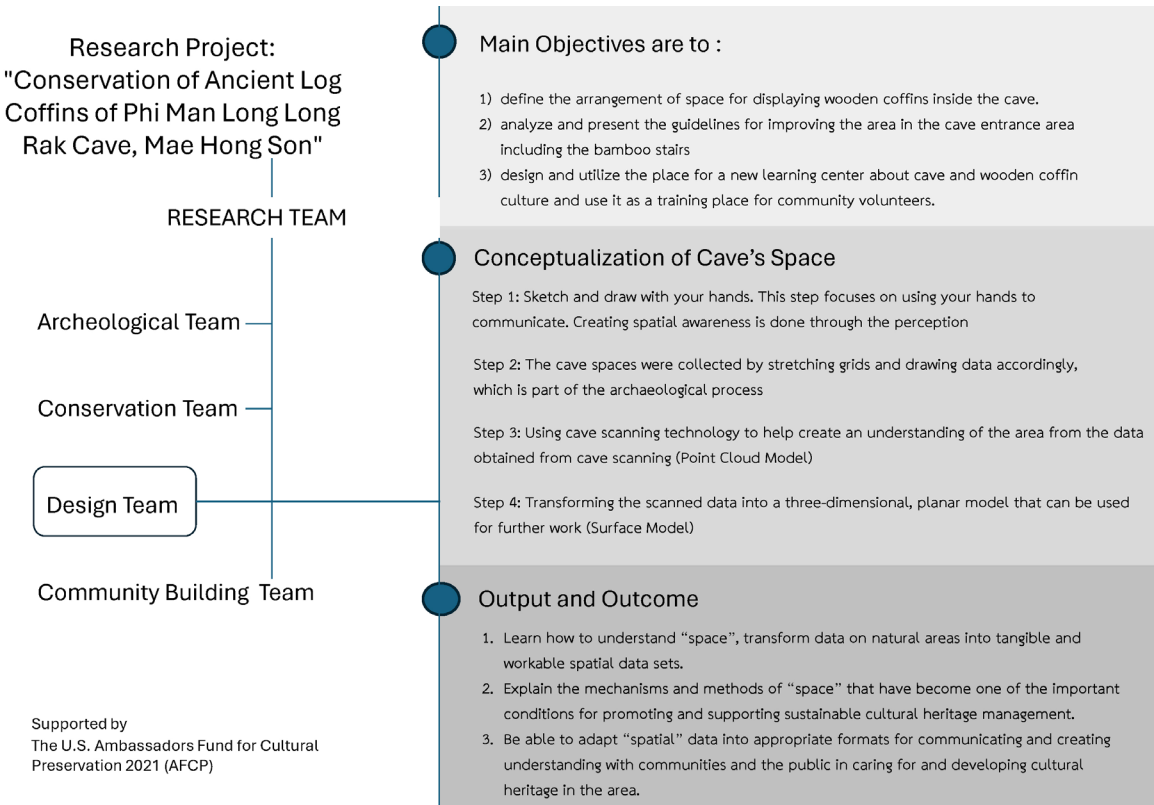


Figure 2. The scope of the spatial work undertaken by the architectural (design) team.

Source: The author

The architects involved in this project had three main tasks, as outlined in Figure 2, and described in more detail as follows:

1. Analyzing the Cave Interior for Wooden Coffin Display

The task involved examining the cave's interior, specifically Room A, which contains numerous wooden coffins in an exceptionally well-preserved state. While many coffins remain intact with their lids and bases well-assembled, several have fallen apart or become dislodged, possibly due to human interference or seismic activity. The primary objective of this task was to use architectural expertise to organize and manage the cave space in a way that enhances its appeal without distorting the original arrangement of the coffins.

2. Proposing Improvements for the Cave Entrance and Stairs

The current entrance to the cave relies on bamboo stairs crafted by local artisans. The challenge was to design a safer and more durable entranceway without altering the spatial context of the cave or causing damage to its surface using modern materials. This effort required a balance between improving accessibility and preserving the natural and cultural integrity of the site.

3. Designing a Community Learning Center

Beyond the cave itself, the project aims to foster local awareness of the significance of the wooden coffin culture and the Long Long Rak Cave. The local community is a key stakeholder in the sustainable conservation of this ancient cultural heritage. To support this goal, the architects were tasked with reimagining the old police station in the Tham Lod area, donated by the community, as a learning center dedicated to the culture of wooden coffins and the Long Long Rak Cave. The proposed activity formats and design guidelines for this center aimed to educate, engage, and inspire the local community while promoting heritage conservation.

The scope of work for task three involved presenting a comprehensive guideline for renovating the old police station into a community learning center. The process needed to be clear and straightforward, with a design logic that harmonized with the surrounding environment. The proposal required exhibition panels be developed that were accessible and easy to understand, ensuring that the design was both practical and implementable.

The scope of work for tasks one and two presented a far greater challenge for the design team than task three. A critical question arose for designers accustomed to working with geometric manipulation and three-dimensional spatial representations: how to develop a spatial concept of a cave? The vastness, mystery, and intricate complexity of the cave's cavities—characterized by overlapping stone walls and irregular forms—present unique obstacles. What methods should be employed to accurately collect data on the cave's dimensions, such as its width and length, while considering the precise locations of the wooden coffins? These challenges and concerns became apparent during the initial survey phase, sparking crucial discussions among the design team about the best approaches to address the project's complexities.

As previously mentioned, this article focuses on the thinking process and resolution of the “conceptualization of the cave's space,” particularly in Room A. This process can be broken down into four steps. Step 1: Sketching and drawing by hand - this initial step emphasized the use of hands as a means of communication. Spatial perception was developed through sensory engagement and direct experience within the cave. The goal was to grasp and convey the overall sense of the empty space intuitively. Step 2: Collecting spatial data using grid lines - in this step, grid lines were stretched across the space, and data were recorded accordingly. This method, part of the archaeological process, documented findings in a flat, two-dimensional format. However, it did not capture the three-dimensional nature of the cave's space. Step 3: Applying cave scanning technology

- to overcome the limitations of flat documentation, cave scanning technology was utilized, producing a detailed Point Cloud. This method created a more comprehensive understanding of the cave's spatial dimensions. Step 4: Transforming scanned data into a 3D model - the data obtained from the scanning process was transformed into a Surface Model, a 3D representation that can be used for further analysis and design.

Once these four steps were completed, the spatial data of the cave were analyzed to achieve several goals, including: (1) design displays that did not disturb the physical integrity of the cave or alter the arrangement of the wooden coffins; (2) develop solutions for improving the bamboo stairs at the entrance while maintaining the natural context of the cave; and (3) facilitate public engagement through tools such as 3D printing, graphics, and virtual walkthroughs, allowing others to experience the Lacquered Coffin Cave area in a meaningful way.

4. Author's Positionality in the Creation of Spatial Concepts



Figure 3. Picture showing the cave's color and texture.

Source: The design team (October 20, 2022)

The process of “creating a spatial concept of a cave” stands as the central focus of this article because “caves” exhibit a wide range of geometric diversity, with angles that are complex, overlapping, and not deliberately crafted or managed by any single individual. Consequently, the traditional body of knowledge and inherited thought framework - those familiar with shaping and prioritizing structures - often rely on “forms” (Forty, 2000). In architectural practice, much of the work operates in a state of ambiguity, where form and thought converge. They evolve through meaning, aesthetics, and functionality, shifting in response to the flow of creative ideas (Evans, 2000). It is not merely about replicating the shape of what is in front of us; an architect's work often involves understanding and perceiving the surrounding space. This process establishes a relationship between the subject being considered and its broader context, ultimately shaping orientation, perspectives, and imagination (Neil, 1997).

In contrast, caves - whether considering their area, surface, or spatial extent - appear to lie outside these conventional frameworks of thought and established methods of geometric management. The typical tools of architectural practice and the thought processes used to imagine and organize “forms” may not be suitable for conceptualizing cave spaces. Therefore, key questions emerge: how to represent the “shape” of a cave space? What approaches could be used to manage and represent the cave's dimensions and spatial complexity? These questions form the core challenges in creating a spatial concept for this cave.

Beyond the challenge of creating a spatial concept of the cave, another crucial factor was the “wooden coffin.” Removing the wooden coffin from its original cave setting would alter the cultural significance of the Wooden Coffin Culture. Therefore, presenting the relationship between the cave and the coffin is vital. However, bringing large numbers of visitors – tourists or community members – into the Lacquered Coffin Cave to view the wooden coffins is neither simple nor necessarily appropriate. The research team needed to consider all available information, including methods of accessing the cave, in consultation with community representatives and government officials, to decide whether and how to open the cave for public visitation. This decision hinged on the cave’s status itself, which is a pivotal concern.

Currently, the Lacquered Coffin Cave is considered as newly discovered. Although there is evidence of intrusion by smugglers who used pieces of coffin lids as firewood, the cave’s interior remains relatively undisturbed by the outside world (Shoocongdej, 2020). The cave’s steep 15-meter descent at the entrance already poses a significant access challenge (Figure 3). Despite the installation of a bamboo ladder crafted by local artisans, opening the area to outsiders remains risky. Access to Room A, which houses multiple coffins and is central to the cave’s importance, requires crawling through narrow passages with limited ventilation. Additionally, the movement of people can stir up fine dust which may be damaging to the coffin integrity.

In discussions with community leaders and national park officials, the research team weighed the benefits against the risks of opening the cave to unrestricted public access. Consequently, designing a spatial concept for the cave not only fulfilled research objectives but also served as a crucial means of communicating with the broader public, helping those who cannot physically enter the cave to see, understand, and imagine the space. In this sense, the cave’s representation became a vital model, enabling others to envision the Lacquered Coffin Cave in a realistic and respectful way.

5. Methods and Findings: Exploring and Understanding the Cave Area

The archaeology and conservation teams had been working in the cave for several years before the design team arrived. By tracing back to 2010, we collected data and findings from earlier archaeological work, reflecting a gradual exploration of the cave area and the untangling of its intricate crevices. For this article, the work steps are not organized chronologically by year but rather by the progression of understanding the “space” of the cave. This process can be divided into four main steps, outlined as follows:

Step 1: Sketching and Developing Spatial Awareness

Our first descent into the cave took place on November 20, 2021. We carefully made our way down a shaky bamboo staircase, with no initial sense of the cave’s dimensions. Due to its convoluted interior and near-total darkness, it was impossible to gauge the size of the cave, particularly in relation to human scale – a key technique architects typically rely on to understand a space’s volume. During this first familiarization, we spent some time allowing our eyes to adjust to the dimly lit environment. Gradually, we noticed more details. In areas where sunlight filtered through and struck the cave walls, we could discern the texture and color of the rock. Beyond a relatively flat, wide area that served as a base for us to stand, there was a descent leading to Room A. We estimated that these rooms were situated about five to six meters below the base level. Turning to the opposite side, away from the stairs we had descended, we noticed a large, upward-curving rock formation. The researchers accompanying us explained that these areas were Rooms B and C. However, for this initial visit, our primary focus was to explore and understand the scale of Room A.

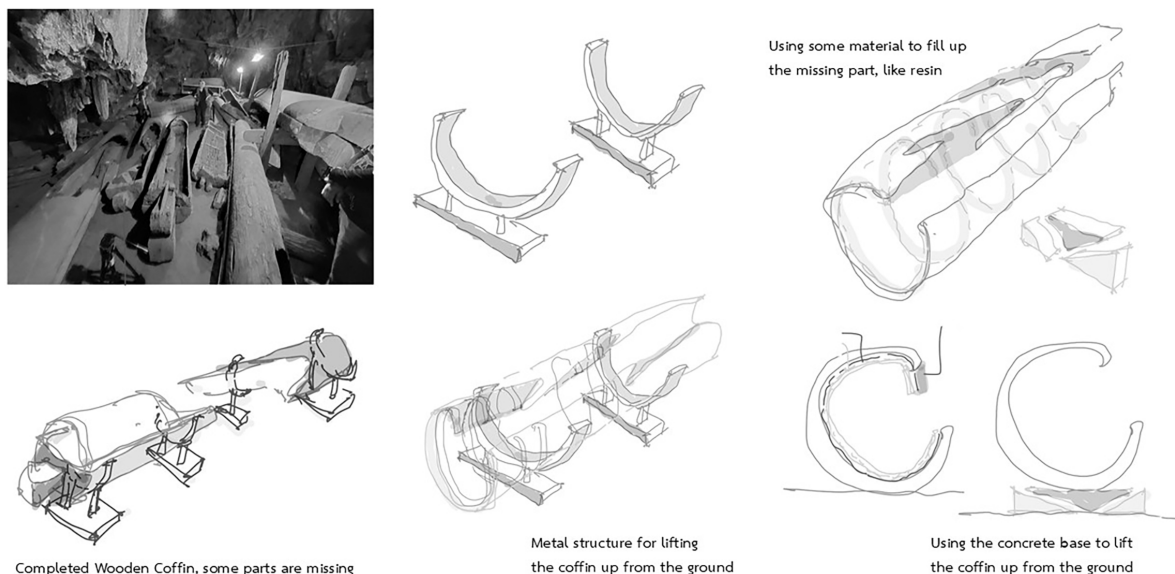


Figure 4. Design sketches illustrating the weight-bearing point for a coffin, which elevates it above ground level to avoid moisture. This supporting element can accommodate various coffin shapes.
Source: The design team (November 20, 2021)

To enter Room A, we had to crawl through a narrow passage in the rocks, measuring roughly 40 centimeters high and 10 meters long. Dust filled the air as we made our way through. After passing this narrow crawl space, we arrived at Room A - our focus for this exploration, where we discovered large wooden coffins. Some of the coffins had fallen and lay scattered, while others remained intact, perched gracefully on wooden beams. One of the research team's goals was to envision the original placement of the coffins before they were disturbed - before smugglers broke pieces of them for firewood - and to imagine the coffins in their complete form with lids properly paired and attached. Such visualization provides valuable insight into the original funeral rites and highlights the cultural significance of these ancient wooden coffins.

However, physically lifting these massive, heavy coffins by hand was unfeasible and bringing in machinery to hoist the lids deeper into the cave was even more challenging. Moreover, our sketching tools faced limitations. It was difficult to accurately map the positions of the coffin lids within the vast interior of the cave. Traditional sketching methods alone could not fully capture the cave's enormous scale. Nonetheless, during our first day inside, we proposed constructing a device to lift the coffins off the ground - preventing excess moisture from accumulating - and to build support points for the more fragile and thin coffins (Figure 4). These supports were needed to accommodate the natural curvature of coffins made from whole tree trunks. Since the coffins often were fashioned using only basic tools, such as a single machete, their shapes vary significantly, requiring a flexible yet stable design for proper preservation.

Step 2 Using the Grid System and Recording



Figure 5. Pictures captured of the archaeological team using a 1 x 1 meter grid system to document spatial distribution and archaeological details of coffin features within the cave.

Source: The archeological team (2013-2015)

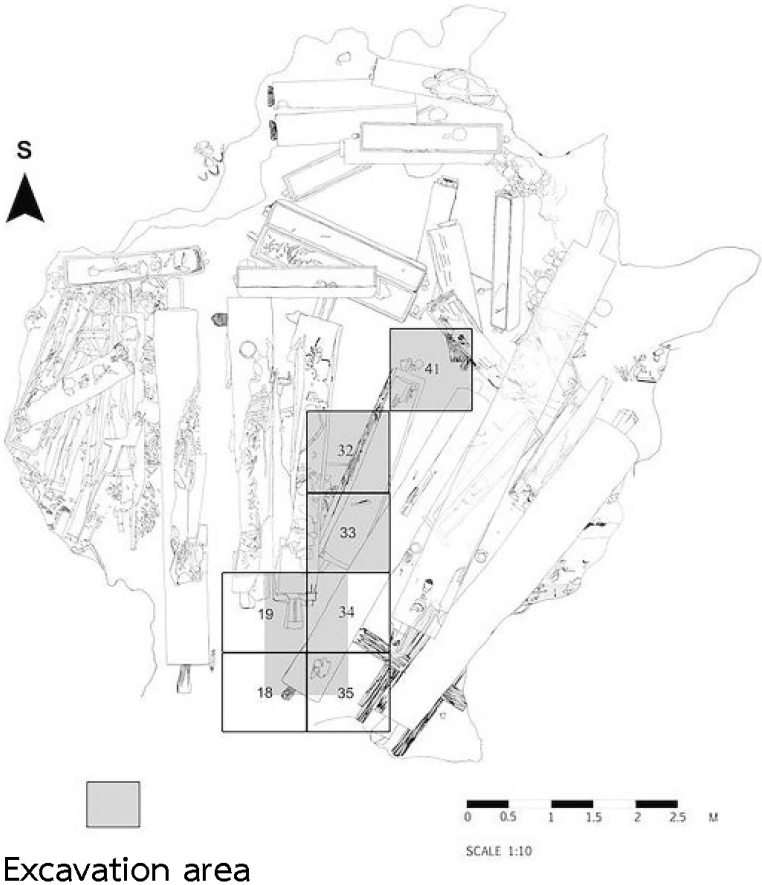


Figure 6. Map of Room A using a 1 x 1 meter grid system to document spatial distribution and archaeological details of coffin features within each grid segment.

Source: The archeological team (2013-2015)

Different research objectives naturally lead to different processes and methodologies. The archaeological team's goal was to meticulously record every detail related to the wooden coffins, ranging from their form and the shape of the coffin head to the DNA of the skeletal remains inside. They aimed to capture each element as accurately as possible with respect to its real-world appearance. To achieve this, the archaeological team used grid mapping. They layed out a 1×1 meter grid on the ground, moving from one grid section to another, and sketched their observations by hand on graph paper at a 1:100 scale (Figure 5). They then transferred these drawings onto tracing paper, later scanning them to ensure the final map mirrored the actual arrangement as closely as possible. Each map must include a north arrow and a scale for accurate reference (Figure 6).

This archaeological work can be traced back to 2010, under the “Project to Investigate and Sustainably Manage Cultural Heritage in Pai - Pang Mapha - Khun Yuam, Mae Hong Son, Phase 3,” which involved surveying and mapping the entire Lacquer Coffin Cave (Rooms A–C). Subsequent studies took place between 2013 and 2015 with the “Project on the Interaction between Prehistoric Humans and the Environment in the Highlands of Pang Mapha, Mae Hong Son,” during which Room A was mapped in detail and excavated. Work continued again in 2021 under the “Prehistoric Humans and Cultural Dynamics Project in the Highlands in Pang Mapha, Mae Hong Son,” culminating in the comprehensive analysis of archaeological evidence.

Interestingly, while sketches can convey the grandeur of the cave, they inherently are limited in illustrating the cave's surface. The complexity of its curves and angles may not be captured precisely in a sketch, and such drawings often lack the level of detail necessary for accurately recording the site's specific features. In contrast, the meticulous drawings produced by the archaeological team flatten the three-dimensional “space” of the cave into two-dimensional data. This method, tied to the chosen grid lines, can only record details at a specific height - anything above or below this horizontal plane is not depicted. As a result, the varying heights of the cave's recesses remain invisible and the relative elevation of the wooden coffins within the cave is omitted.

Both approaches - sketching and grid-based recording - have their merits and limitations when it comes to understanding and addressing the relationship between the cave's spatial layout and the wooden coffins. Consequently, we sought a new method to conceptualize the cave space in conjunction with the coffins, turning to modern technology for assistance. By scanning the cave's surface and creating a computer-generated model, we can visualize the three-dimensional volume of the cave, along with the specific positions of its features. This technology, referred to as a Point Cloud, offers the possibility of accurately representing the cave's dimensions and the coffin placement that cannot be achieved through the sketching and two-dimensional mapping techniques.

Step 3: 3D Scanning Technology and the Point Cloud

After collectively assessing the limitations of conceptualizing the cave's spatial dimensions, the team decided to utilize modern technology that enables 3D volumetric simulations of the cave's empty space. This method captures the surface positions of the cave using laser scanning, while simultaneously collecting depth, curvature, angular formations, and texture/color data of both the cave interior and the wooden coffins inside. This technology is known as the Point Cloud. The laser scanner operates through three main processes: 1) Data Collection Process - the laser scanner emits laser beams that strike different surfaces. The points where the laser touches the surfaces create millions of laser points, forming what is known as the Point Cloud; 2) Data Transformation Process - this stage converts the millions of scanned points into a single Point Cloud—a dataset that generates a simulated surface representation using a coordinated reference system; 3) 3D Model

Construction - the final step transforms the Surface Model into a full 3D model that can be measured, modified, and adjusted. Unlike a simple surface representation, this model allows for spatial manipulation and precision-based analysis. This advanced scanning technology enhances the accuracy of cave mapping and spatial understanding, offering a comprehensive and adaptable tool for further research and conservation efforts.

The Point Cloud is an essential component of laser scanner technology, which is used for surveying and data collection. The technique measures “...the distance from the sensor to nearby surfaces with millimeter to centimeter accuracy at speeds of thousands to hundreds of thousands of point measurements per second” (Tang et al., 2010) . Each scanning session involved the emission of laser beams from the scanner’s fixed position, targeting surrounding surfaces. The result was the generation of millions of laser points, forming a dense Point Cloud that captured the spatial characteristics of the area. In cases where the scanned surfaces included curves, overlapping structures, or occluded areas, the scanner was relocated to multiple positions to ensure complete data capture. Often, digital cameras are integrated into the scanning process to simultaneously record surface colors and textures, enhancing the accuracy and detail of the dataset (Tang et al., 2010) . The various positional data points within the Point Cloud were later processed, aligned, and integrated to form a composite digital representation. This dataset was then transferred into a 3D simulation environment, making it usable for further spatial analysis, conservation planning, and architectural applications (Javaid et al., 2021).



Figure 7. The cave laser scanning team entering the cave.

Source: The cave scanning team (March 2022)

The cave laser scanning team conducted their survey and 3D scanning in March 2022, beginning with determining scanning points for the laser beam projection. The device used for this process is known as a 3D LiDAR Scanner, which emits laser beams in all directions. When the laser hits a surface, it records the distance from the impact point back to the reference position (the scanner’s location), while simultaneously capturing surface images. The scanner collected these data points and, to ensure maximum coverage, the device was relocated to multiple positions around the cave. In areas with overlapping rock formations or narrow crevices, an additional handheld scanner was used to capture finer details, ensuring a comprehensive dataset. While the laser scanner is in operation, the team also utilized a high-resolution digital camera to capture color and surface textures, which were later integrated into photogrammetric software for further processing (Javaid et al., 2021).

This process combined Point Cloud - which consists of spatially coordinated points in a 3D system - with surface imagery, in what is referred to as the data transformation process. According to Romchat (R. Chuchoti, personal communication, March 20, (2022), a 3D scanning expert, "Point Cloud is a method of capturing an object's shape and structure—in this case, the surface enclosing the void within the cave. By adding RGB color values to these points, it is as if we are 'painting' the surface, creating a foundational database for 3D modeling." (See Figure 7) Compared to conventional surveying methods, this approach offered higher accuracy. Laser scanners and Point Cloud are widely used in architectural surveys, conservation projects, and structural restoration planning (Javaid et al., 2021). While this technology has been applied to complex curved and intricately shaped structures (Wi et al., 2020), it rarely has been used for scanning cave interiors—making this project an innovative application of 3D scanning in a natural, subterranean environment.

Step 4: From Points to Surface Model

A detailed explanation of the scanning technique, or how the data were converted into 3D images by computer programs, is not the focus of this article. Instead, our primary goal is to illustrate how spatial concepts of the Coffin Cave - especially in Room A - were derived, considering the wooden coffins. It is important to note that the 3D Point Cloud generated from the scanner data was not fully leveraged for spatial purposes, due to the following limitations: (1) Point-Based Model - the resulting model consisted of countless points; what appears to be surface color and structure is actually a dense arrangement of these points. Because it is entirely point-based, modifying the model - for example, manipulating spaces or adding new elements - is difficult; (2) Transparency and Limited Measurability - the Point Cloud was somewhat like a translucent "smoke" of overlapping points, making it difficult to accurately measure distances between specific points. Selecting precise coordinates for measurement within this transparent model is challenging; and (3) Data Size and Processing Power - the model's massive dataset requires high-end computer systems capable of handling large amounts of information quickly. Standard computers generally are insufficient. Given these constraints, the research team and scanning team agreed to convert the Point Cloud into a Surface Model - essentially transforming the points into continuous surfaces. Additionally, they decided to isolate Room A to keep file sizes manageable. The resulting surface-based model allowed for easier manipulation, measurement, and the addition of new elements for subsequent design or conservation steps (Figure 8).

From the early stage of understanding the cave's expansive layout and noting where the wooden coffins lie, efforts began with a grid-based technique - drawing everything that appeared within each grid square. This two-dimensional approach was later enhanced using modern technology that allowed for a more detailed simulation of the cave's surface, including color and coffin positions, by means of laser scanning. The resulting data, consolidated into the Point Cloud, subsequently were converted into a Surface Model, linking each point to form a three-dimensional representation (Figure 9). This 3D model enables more precise modifications, allowing adjustments or additions without physically impacting the cave. However, during the process of creating a comprehensive spatial concept for the cave and the wooden coffin's placement, various challenges and considerations arose regarding how best to visualize and preserve the site's integrity (Figure 10).

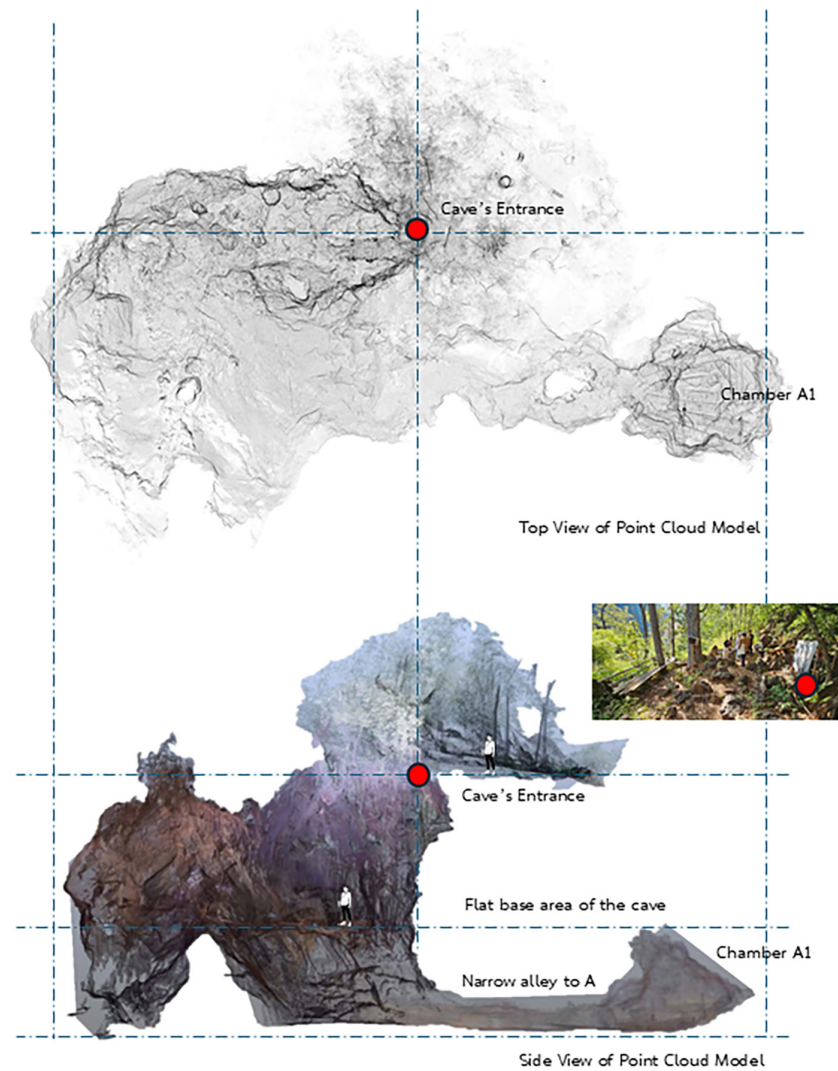


Figure 8. Coffin Cave scan data gathered via LiDAR and converted into the Point Cloud, shown in both plan and side views. Reference points include the cave entrance, the cave's flat base area, and the narrow passage leading to Room A.

Source: The cave scanning technicians (March 2022)

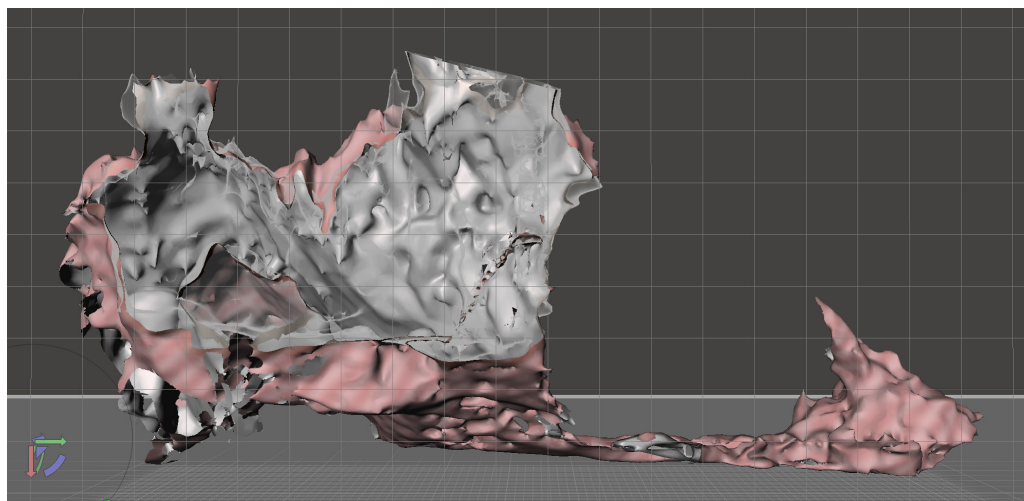


Figure 9. A sectional view illustrating both the cave's outer surface and interior contours. The data, initially captured as the Point Cloud, were converted into a Surface Model.

Source: The cave scanning technicians (March 2022)

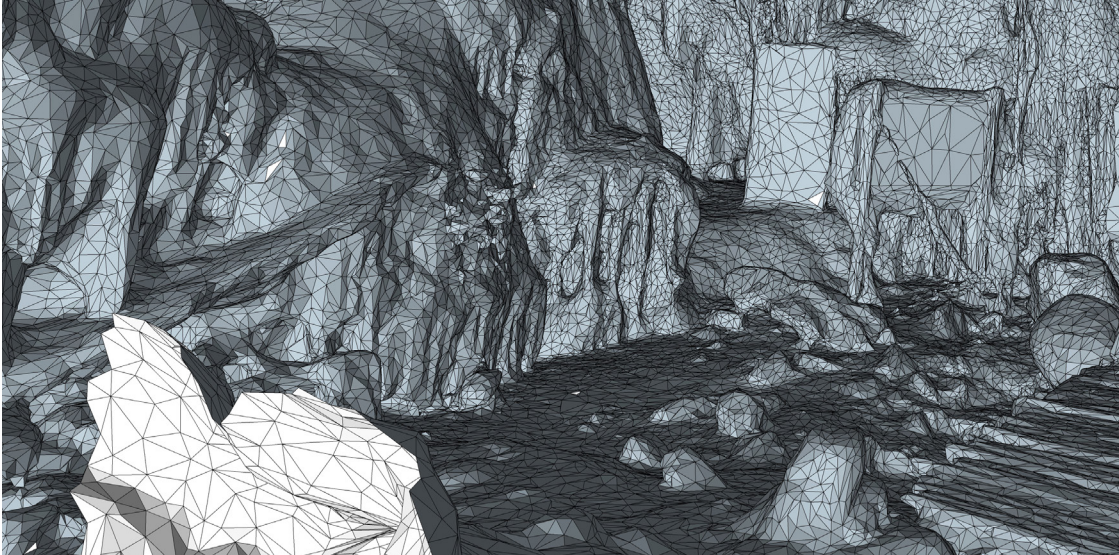


Figure 10. A magnified view illustrating how lines from the Point Cloud are converted into a Surface Model.

Source: The cave scanning technicians (March 2022)

6. Discussion and Conclusion: Bridging Physical and Digital Realities in Spatial Conceptualization

The spatial conceptualization process can be seen as analogous to the creation of virtual environments in the digital world, such as those often found in online gaming platforms. It represents an effort to establish a connection between physical and digital, with the key objective being to create a sense of continuity between the real and virtual worlds (Taylor, 2011). This approach expands the boundaries of perception and imagination. It is no surprise that major architectural landmarks have been digitally reconstructed in virtual environments to foster an augmented reality (AR) experience. Similarly, these technologies are applied widely in navigation systems such as Google Maps and Google Earth, allowing users to develop familiarity with virtual representations of real-world locations (Shevchuk et al., 2022).

The spatial conceptualization of the cave and the positioning of the wooden coffins does not specifically aim to merge real and virtual worlds, but instead it focuses on the possibilities of conservation and sustainable development within the cave environment. The primary goal is to introduce new elements into the cave without disturbing its surfaces or compromising the fragile cave ecosystem. Through experimental spatial data collection, the design team discovered that utilizing laser scanners, the Point Cloud, and Surface Models allowed for a coordinated spatial framework, enabling precise measurement and adjustments. These methods provide accurate three-dimensional documentation of the cave's width, length, and height, effectively demystifying its complex and intricate structure, making it easier to understand, visualize, and modify as necessary.

One of the key responsibilities assigned to the design team was to explore ways to restore and display the wooden coffins in their original condition or to assess the possibility of reassembling scattered coffin lids. By utilizing 3D printing technology, the team was able to present an overall spatial visualization of the cave in relation to the coffins (Figure 11). Additionally, the team sought to replace the deteriorating temporary bamboo staircase with a stronger, more durable structure, ensuring that the new stair placements did not interfere with the cave's natural form (Figure 11).

In the future, this comprehensive dataset could be utilized to develop a virtual walkthrough of the cave, particularly Room A, allowing individuals to experience the cave and the wooden coffins remotely. This would eliminate the need to physically travel to Pang Mapha District, descend 15 meters into the cave, or crawl through narrow underground passages to view the Phi Man wooden coffins. This innovative application of 3D scanning and spatial modeling not only preserves and documents the cave's historical and cultural significance but also enhances accessibility and engagement with the site, ensuring that its legacy is preserved and shared with a wider audience.



Figure 11. Implementation of how to use a Surface Model, analyzing the positions of various support points and referencing the original bamboo ladder (left; Source: The design team, January 2024); and new ladder design is positioned to align with the internal context of the cave (right; Source: The archeological team, January, 2025).

For the design team, “space” not only is a raw material for their work but also a source of knowledge for learning and understanding, as well as a key focus for adjustment and enhancement. When tasked with the critical mission of collaborating in an integrated cross-disciplinary effort - alongside the archaeology team, conservation team, and community awareness incubation team - the design team concentrated on creating a spatial concept of the cave in relation to the wooden coffin.

To achieve this, a variety of techniques were employed to analyze and interpret the spatial characteristics of the cave. These methods aimed to uncover possibilities for adjustments, whether within Room A, which houses the wooden coffins, or in the cave hall, where the bamboo stairs are situated. Benefits from creating this concept include:

1. Understanding the Transformation of Natural Space into Geometric Space

The design team explored the potential of transforming the data set of natural space - a raw, unstructured representation of the cave - into a geometric space model with tangible, measurable surfaces for further work. The cave data, which included dimensions such as width, height, depth, and niches, enabled a visualization that portrayed the cave as a grand, complex, and captivating space. However, the entire dataset was not utilized in practice. During discussions with the archaeology team, it became evident that certain aspects, such as the height of the cave and the height at which the coffins were placed, were less critical than the location of the cave itself. For instance, the Coffin Cave is classified as a cave for commoners, as evidenced by the discovery of cultural artifacts associated with daily life, such as pots and threads. This contrasts with larger, more prominent caves that are associated with higher social classes and contain artifacts of greater significance (R. Shoocongdej, personal communication, January 26, 2024) .

2. Space as a Key Condition in Managing Cultural Heritage

It has been emphasized that “space” is a critical factor in the management of valuable cultural heritage, as these heritages intrinsically are tied to their place and location. The physical limitations of certain sites - such as restricted access and fragility - highlight the importance of creating representative images that can effectively communicate their significance. By utilizing such representations, the public and local community gain an opportunity to understand and appreciate the existence of these ancient, delicate cultures without needing to physically visit the site. This approach helps to mitigate the impact of excessive human activity on vulnerable areas. Moreover, these visual representations and the accompanying information foster a deeper understanding of the community’s cultural heritage. This, in turn, cultivates a sense of awareness, appreciation, and responsibility toward preserving and sustainably maintaining these treasures for future generations.



Figure 12. Picture of the original police station at the entrance of Nam Lod Cave (left; Source: The design team, March 2022); and graphic representation of the renovated learning center after transformation, not only designing the exhibition space inside, but also adding a public space for the community (right; Source: The design team, January 2024).

3. Expanding the Role of the “Space” in Conservation and Development

The “space” concept was leveraged to expand the scope of conservation and development efforts. In addition to gathering spatial data to create representative images, the design team adapted and reinforced the “space” as a key condition for both conservation and community development. As part of their mission, the design team was tasked with renovating the original police station, located in the marketplace near the entrance to Nam Lod Cave, just a few kilometers from Long Long Rak Cave. This building, entrusted to the research team by the community and the forestry department, was transformed into a learning center (Figure 12). The design team recognized that the “space” of this learning center was not just a space for presenting information from the cave. Beyond hosting exhibitions of ancient artifacts or showcasing knowledge from archaeological excavations, the learning center was envisioned as a platform to foster a sense of pride and stewardship among community members for their cultural heritage. Planned activities for the learning center include training local youth to serve as community guides, hosting community exhibitions to celebrate local culture and history, and organizing handicraft workshops to generate income and sustain traditional skills. Thus, the “space” of the learning center extends beyond its role as a physical exhibition space. It becomes a vital mechanism for strengthening the relationship between the caves and the community, promoting cultural appreciation, and supporting sustainable development.

The “cave” in this article is not merely an abstract image, metaphor, or allegory symbolizing mystery and hiddenness. It refers to an actual location in Pang Mapha, Mae Hong Son. Ordinarily, the design team would not be directly involved in the work of archaeologists, whose research focuses on excavating historical

traces and interpreting cultural insights from artifacts. However, the research project “Conservation of Ancient Log Coffin of Phi Man Long Long Rak Cave, Mae Hong Son” is an exception. In this project, the design team had the rare opportunity to engage in integrated, cross-disciplinary collaboration. This involvement allowed them to delve into their expertise and apply the tools and techniques they were trained in. The “cave’s space” gradually was documented and revealed, creating an evolving awareness and understanding of its spatial characteristics.

The “cave’s space” and the wooden coffins exist in a symbiotic relationship, inherently connected and mutually supportive. They cannot be understood in isolation. Thus, the design team’s role became one of re-presenting the “cave’s space” in its relationship with the wooden coffins, as they should exist together within the context of the “wooden coffin culture” and the “Long Long Rak Cave.”

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Human Subjects

This study is not include human subjects.

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Data Availability Statement

The data from this research has been compiled and is on display publicly at the exhibition building located at the entrance to Tham Nam Lod Cave, Pang Mapha District. Some sensitive data, such as the data generated from laboratory tests of findings at an excavation site, may be obtained from the corresponding author upon reasonable written request.

Use of Generative Artificial Intelligence (AI) and AI-Assisted Technologies

There is no use of AI and AI-Assisted Technologies in this research.

Author Contributions

Conceptualization, S.S. and R.S.; methodology, S.S. and R.S; resources, R.S., S.K. and V.D; writing-original draft preparation, S.S. and R.S; writingreview and editing, S.S.; supervision, R.S; project administration, S.K. and V.S.; funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

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