ALMUSTOFA: Journal of Islamic Studies and Research
Vol. 03 , No. O2, Desember 2026 II Halaman: 208 – 226
e-ISSN: 3090-0247 II D.O.I. Jurnal: https://doi.org/10.23960/almustofa
https://ejournal.bamala.org/index.php/almustofa/index

Mosque Architecture as a Contextual Resource for Islamic Physics Education: An Ethnophysical Analysis of Geometry and Acoustics

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Article History:
Received: 13/11/2026
Revised: 14/11/2026
Accepted: 14/11/2026

Keywords:
Ethnophysics;
Mosque Architecture;
Dome Geometry;
Architectural Acoustics;
Islamic Physics Education

Abstract: *Mosque architecture represents a valuable yet underexplored context for connecting physics education with Islamic cultural and intellectual heritage. This study examines the physical principles embedded in mosque dome architecture, particularly structural geometry, static equilibrium, sound reflection, resonance, and reverberation, and explores their potential as contextual resources for Islamic physics education. Employing a descriptive-analytical literature review, the study synthesizes relevant literature on ethnophysics, Islamic architecture, structural mechanics, and architectural acoustics. The analysis identifies the mosque dome as a physical system in which geometric configurations influence structural behavior, while curved surfaces and interior spatial characteristics shape sound propagation and acoustic performance. Building on these findings, the study proposes the Mosque-Based Ethnophysics Learning Framework (MELF), a conceptual framework consisting of four interconnected stages: Cultural Recognition, Scientific Exploration, Conceptual Reconstruction, and Islamic Value Reflection. Through these stages, students are encouraged to observe familiar architectural features, investigate the scientific principles underlying them, reconstruct relevant physics concepts, and reflect on Islamic values such as tawazun (balance), tafakkur (contemplation), and ihsan (excellence). The framework positions mosque architecture not merely as a cultural and religious heritage, but also as a meaningful learning environment for contextualizing abstract physics concepts. As a conceptual contribution derived from literature analysis, MELF requires further empirical investigation to establish its pedagogical effectiveness and applicability across different educational settings.*

INTRODUCTION

Physics education plays a fundamental role in developing scientific literacy, analytical reasoning, and students' ability to understand natural phenomena. However, one persistent challenge in physics instruction is the tendency to separate scientific concepts from the cultural and social environments in which students develop their knowledge. Physics is frequently presented through mathematical equations, abstract principles, and standardized examples, while its manifestations in everyday life and cultural heritage receive comparatively limited attention. This situation can create a gap between formal scientific knowledge and students' lived experiences, making it difficult for learners to recognize the relevance of physics beyond classroom activities. Consequently, contemporary physics education requires approaches that connect scientific reasoning with meaningful social, cultural, and environmental contexts. Contextual and culturally responsive science education offers an important pedagogical

ALMUSTOFA: Journal of Islamic Studies and Research
Vol. 03 , No. O2, Desember 2026

foundation for addressing this challenge by recognizing students' cultural backgrounds as potential resources for constructing scientific understanding (Aikenhead & Jegede, 1999; Cobern & Aikenhead, 1998).

Within this educational perspective, ethnophysics provides an opportunity to examine how physical principles are embedded in cultural practices, traditional technologies, and architectural heritage. Ethnophysics does not merely use cultural objects as illustrations of scientific concepts; rather, it explores the physical knowledge underlying cultural products and activities and considers how such knowledge can be reconstructed into meaningful learning experiences. This perspective is consistent with the broader concept of culturally situated knowledge, which recognizes that learning is influenced by the relationship between formal instruction and the knowledge developed within students' communities (Moll et al., 1992; Snively & Corsiglia, 2001). Recent research has demonstrated the potential of ethnophysics in transforming traditional cultural practices into contextual physics learning resources. Studies involving traditional dances, local architectural structures, and traditional technologies illustrate that physical concepts can be identified and explored through objects that are familiar within particular cultural environments (Faizah et al., 2025; Fakhruddin et al., 2025; Firdaus et al., 2025). These developments suggest that cultural heritage should be understood not only as a historical asset but also as a potential source of scientific and pedagogical knowledge.

Among the various forms of cultural heritage, mosque architecture represents a particularly relevant context for developing culturally grounded physics education. Mosques are significant religious and social spaces within Muslim communities, but their architectural structures also embody mathematical, mechanical, and acoustic principles. Their architectural elements, particularly domes, provide observable examples of geometric configurations, structural equilibrium, sound propagation, and wave reflection. These characteristics establish a meaningful connection between scientific concepts and students' religious and cultural environments. Rather than positioning religious architecture exclusively within the domains of history or religious studies, an ethnophysical perspective enables mosque structures to be examined as physical systems that can be investigated through scientific observation and reasoning. Islamic architectural heritage, therefore, offers an opportunity to connect scientific literacy with cultural appreciation without compromising the conceptual foundations of physics.

From a structural perspective, mosque domes provide a contextual example for understanding geometry, static equilibrium, and the distribution of mechanical forces. A dome is a curved structural form through which loads are transferred toward supporting elements, with its mechanical behavior influenced by geometry, material properties, structural thickness, and

loading conditions. Understanding these characteristics requires students to examine the relationship between force, equilibrium, compression, and structural stability. Hasan and Hill (1986) documented the historical development of Islamic technology, including architectural innovations that demonstrate the sophisticated relationship between mathematical knowledge and engineering practices in Islamic civilization. These historical developments can be translated into educational activities through geometric modeling, observation of architectural forms, and elementary analysis of structural forces. For example, students can construct simplified dome models to investigate how curved configurations distribute loads and how geometric variations influence structural stability. Such activities provide opportunities to connect abstract concepts of mechanics with observable architectural phenomena.

In addition to structural geometry, mosque domes provide a valuable context for exploring architectural acoustics. Sound behavior within enclosed spaces involves several interconnected phenomena, including reflection, absorption, resonance, and reverberation. These processes directly influence the quality of sound transmission and speech intelligibility, particularly during religious activities such as prayer, Qur'anic recitation, and sermons. One important parameter in room acoustics is reverberation time, defined as the time required for sound energy to decrease by 60 decibels after the sound source has stopped. The Sabine equation provides a theoretical basis for estimating reverberation time through the relationship between room volume and total sound absorption (Kinsler et al., 2000; Kuttruff, 2016; Long, 2006). Research on mosque acoustics has also demonstrated the relevance of architectural geometry and interior materials in determining acoustic characteristics. Yani (2020) examined the acoustic quality of Raudhaturrahman Mosque in Padang Tiji, while Ridhatiana and Wardoyo (2021) investigated the relationship between spatial configuration, dome geometry, and acoustic performance at Al-A'zhom Grand Mosque in Tangerang. These studies provide contextual evidence that mosque architecture can be investigated through the scientific principles of sound waves and room acoustics.

Nevertheless, the educational significance of mosque acoustics extends beyond explaining physical phenomena. Students can investigate how sound behaves in different architectural spaces, compare the effects of surface materials, and examine why certain spatial configurations may produce longer reverberation or reduced speech intelligibility. Such activities can introduce students to the relationship between theoretical models and real-world conditions. They also encourage scientific reasoning through observation, measurement, comparison, and interpretation. The integration of architectural acoustics into physics education therefore creates

an opportunity to develop conceptual understanding while introducing students to the practical relevance of wave phenomena in their immediate environments.

Furthermore, the use of mosque architecture as a learning resource provides an opportunity to establish a meaningful relationship between scientific knowledge and Islamic educational values. Islamic intellectual traditions emphasize reflection, observation, and the pursuit of knowledge as important dimensions of human development. The Qur'anic concepts of *tawazun* (balance) and *tafakkur* (reflective contemplation) can provide ethical and spiritual perspectives through which students interpret the order and complexity of the physical world. In this context, the study of structural equilibrium can be associated reflectively with the value of balance, while the observation of architectural forms and acoustic phenomena can encourage contemplation of the signs of creation. However, the integration of Islamic values must maintain clear epistemological boundaries. The Qur'an should not be treated as a substitute for scientific theories or as direct empirical evidence for mathematical equations. Instead, religious texts can function as sources of ethical reflection and spiritual meaning that complement scientific investigation. This distinction is essential for ensuring that the integration of science and Islamic values remains academically responsible and educationally meaningful.

Despite the growing interest in ethnophysics and culturally contextualized science education, several conceptual and pedagogical issues remain insufficiently addressed. Existing studies have explored physical principles in traditional dances, cultural technologies, and architectural structures, demonstrating the potential of local knowledge for physics learning (Faizah et al., 2025; Fakhruddin et al., 2025; Mahyudin & Hasan, 2024). However, the simultaneous examination of structural geometry and architectural acoustics within mosque architecture as interconnected dimensions of a single educational resource requires further development. Moreover, studies examining mosque acoustics have primarily concentrated on architectural performance and the technical evaluation of sound environments, while ethnophysics research has generally focused on identifying physical concepts within cultural objects. The pedagogical transformation of these findings into an integrated learning framework remains an important area for further investigation. Fitrian and Suhendra (2024) highlight the development of ethnophysics-based learning media, while Lestari et al. (2026) identify continuing challenges in the implementation of ethnophysics within secondary physics education. These developments indicate the need to move beyond the identification of physical phenomena toward a more systematic formulation of culturally grounded learning resources.

Addressing this gap, the present study examines mosque architecture as a contextual resource for Islamic physics education through an ethnophysical analysis of dome geometry and

architectural acoustics. Specifically, it investigates the physical principles associated with structural equilibrium, geometric configuration, sound reflection, and reverberation, and explores their potential transformation into contextual learning activities for secondary-level physics education. The study also examines how Islamic values can be incorporated through reflective learning without conflating religious interpretation with scientific explanation. Its principal contribution is the formulation of an integrated pedagogical perspective that connects architectural heritage, fundamental physics concepts, and Islamic educational values. By positioning mosque architecture as a source of scientific inquiry and cultural reflection, this study seeks to expand the conceptual foundation of ethnophysics and provide a basis for developing more contextual, culturally responsive, and spiritually meaningful physics education.

RESEARCH METHODOLOGY

This study employed a qualitative library research design with a descriptive-analytical approach to examine the physical principles embedded in mosque architecture and their potential application in Islamic physics education. Library research was selected because the investigation focused on previously published scientific knowledge, theoretical perspectives, and documented architectural phenomena rather than collecting new experimental or field-based measurements. This approach enabled the researchers to examine the relationship between architectural geometry, structural equilibrium, room acoustics, and culturally grounded science education. Literature-based research is particularly relevant for synthesizing existing knowledge and developing conceptual understandings of an emerging research area (Snyder, 2019; Whittemore & Knafl, 2005). The analysis was directed toward three interconnected dimensions: the physical principles underlying mosque dome geometry and structural mechanics, acoustic phenomena associated with sound reflection and reverberation, and the pedagogical integration of these concepts with Islamic educational values (M. Mahbubi, 2025/2025).

Relevant literature was identified through Google Scholar and the Garuda academic publication database using combinations of Indonesian and English keywords, including *ethnophysics*, *mosque dome acoustics*, *dome geometry physics*, *Islamic architecture and physics*, *contextual physics learning*, and *Islamic science education*. The selection process prioritized peer-reviewed journal articles and academically recognized books that addressed mosque architecture, structural mechanics, architectural acoustics, ethnoscience, and culturally contextualized physics education. Publications from 2016 to 2026 were prioritized to ensure the relevance of contemporary research, while foundational publications in physics, acoustics, and research methodology were retained regardless of their publication year. Literature was included

when it provided identifiable theoretical, methodological, or empirical contributions relevant to the research objectives and was available in full text. Opinion-based publications without identifiable scholarly foundations and materials unrelated to the research focus were excluded. These principles were adopted to maintain the relevance, transparency, and methodological appropriateness of the literature selection (Grant & Booth, 2009; Snyder, 2019).

The collected literature was examined through a process of identification, selection, extraction, and thematic synthesis. Information extracted from each publication included the authors, publication year, research objectives, methodological approaches, theoretical foundations, principal findings, and relevance to the present investigation. The extracted information was subsequently organized into a literature matrix to facilitate comparison across different research domains. Qualitative content analysis was employed to identify recurring concepts, relationships, and patterns within the selected sources. The analysis was organized around three principal themes: architectural geometry and structural equilibrium, acoustic characteristics of mosque spaces, and the integration of scientific concepts with Islamic educational values. These themes were then interpreted collectively to establish the relationship between physical phenomena and their potential transformation into contextual learning experiences. The analytical procedures were informed by established approaches to qualitative content analysis and thematic synthesis (Braun & Clarke, 2006; Hsieh & Shannon, 2005; Thomas & Harden, 2008).

The trustworthiness of the analysis was maintained through source triangulation by comparing findings from architectural history, established physics and acoustics literature, and peer-reviewed educational research. Claims concerning structural mechanics and acoustic phenomena were examined against established scientific explanations, while pedagogical interpretations were evaluated in relation to relevant educational theories. Particular attention was given to distinguishing documented scientific findings from the researchers' conceptual interpretations. An audit trail was maintained through literature matrices and documented selection criteria to support transparency and consistency in the analytical process (Miles et al., 2014; Neergaard et al., 2009; Wilson & Anagnostopoulos, 2021). The resulting educational framework is therefore presented as a theoretically informed pedagogical proposition rather than an empirically validated instructional model.

HASIL DAN PEMBAHASAN

Mosque Dome Architecture as a Physical System: Integrating Structural Geometry and Acoustic Phenomena

Mosque architecture provides a distinctive context for examining the relationship

ALMUSTOFA: Journal of Islamic Studies and Research
Vol. 03 , No. O2, Desember 2026

between physical principles, cultural heritage, and the built environment. Among its architectural elements, the dome represents a particularly valuable object of scientific investigation because its structural configuration and interior spatial characteristics involve multiple physical phenomena. Its curved geometry determines how structural loads are transferred toward supporting elements, while its enclosed volume and reflective surfaces influence the propagation and distribution of sound waves. These characteristics indicate that mosque architecture should not be understood exclusively through its religious symbolism or aesthetic expression. It can also be examined as a physical system in which mathematical relationships, mechanical equilibrium, and acoustic processes operate simultaneously. From an ethnophysical perspective, this interpretation positions architectural heritage as a source of scientific knowledge that can be investigated through observation, mathematical reasoning, and contextual analysis (Hasan & Hill, 1986; Snively & Corsiglia, 2001).

The first dimension of this physical system concerns the relationship between dome geometry and structural mechanics. A dome is a curved structural shell designed to transfer loads from its surface toward supporting walls, columns, or other structural components. Unlike a conventional flat roof, its curved configuration allows forces to be transmitted through the shell, principally through meridional and circumferential stress distributions. Depending on its geometry, material characteristics, thickness, and boundary conditions, the structure may experience different combinations of compressive forces, tensile forces, and horizontal thrust. Consequently, the mechanical behavior of a dome cannot be explained simply by observing its symmetrical appearance. Its structural performance depends on the interaction between geometric configuration, applied loads, material resistance, and supporting conditions. This relationship is consistent with the fundamental principles of shell structures and the mechanics of masonry construction, in which the geometry of a structure plays an important role in determining its capacity to maintain equilibrium (Billington, 1982; Heyman, 1995).

From the perspective of classical mechanics, the structural stability of a mosque dome can be understood through the principles of static equilibrium. A structure is considered to be in static equilibrium when the resultant forces and moments acting upon it are zero, expressed mathematically as $\Sigma F = 0$ and $\Sigma M = 0$. In a dome structure, these conditions explain how its self-weight and external loads are transferred through the curved shell toward the supporting walls, columns, and foundations. The distribution of internal forces is influenced by several structural parameters, including the dome's curvature, thickness, material properties, and support conditions. Consequently, different dome configurations, such as hemispherical, pointed, onion-shaped, and shallow forms, may produce distinct patterns of compressive stress, tensile stress,

and horizontal thrust. Understanding these relationships demonstrates how architectural geometry influences structural behavior and determines the capacity of a dome to maintain equilibrium under different loading conditions.

For example, changes in the curvature and height of a dome can influence the magnitude and direction of horizontal thrust at its supports. However, no particular dome shape can be considered structurally superior without considering its material properties, thickness, dimensions, and support system. This distinction is important because it demonstrates that architectural geometry is not merely a visual characteristic but an essential variable in structural performance.

The mathematical dimension of dome architecture further illustrates how physical knowledge can be reconstructed through measurable relationships. A hemispherical dome with a radius of 10 meters has a curved surface area of approximately 628.32 square meters, calculated using the equation \(A=2\pi R^2\). This relationship provides an accessible example for examining surface geometry, spatial measurement, and material estimation. More importantly, it illustrates how mathematical abstraction can be connected to an architectural object that students encounter in their cultural and religious environments. Nevertheless, the calculation represents an idealized hemispherical model and does not necessarily correspond to the actual surface area of a constructed mosque dome. Architectural variations, decorative layers, structural thickness, and differences in curvature must be considered when applying mathematical models to real buildings. Thus, the educational value of geometric analysis lies not only in obtaining numerical results but also in understanding the assumptions and limitations underlying scientific representations.

The second dimension concerns the acoustic behavior of mosque interiors, particularly the relationship between dome configuration, sound reflection, and reverberation. Sound produced by an imam or preacher propagates through the interior space and interacts with the ceiling, walls, floor, and other architectural surfaces. These interactions generate reflected sound waves that reach listeners through different propagation paths and at different times. The resulting acoustic environment is determined by the interaction of room volume, geometric configuration, surface absorption, sound diffusion, and source-receiver positions. Consequently, the presence of a dome does not automatically guarantee either good or poor acoustic quality. Its influence must be understood in relation to the complete spatial and material characteristics of the building (Abdou, 2003; Kinsler et al., 2000; Kuttruff, 2016; Long, 2006).

One of the most important parameters for evaluating this phenomenon is reverberation time, which refers to the time required for the sound pressure level to decrease by 60 decibels

ALMUSTOFA: Journal of Islamic Studies and Research
Vol. 03 , No. O2, Desember 2026

after the sound source has stopped. The Sabine equation, expressed as \(T=0.161V/A\), provides a simplified mathematical model for estimating reverberation time, where \(T\) represents reverberation time in seconds, \(V\) represents room volume in cubic meters, and \(A\) represents the equivalent sound absorption area in square meters sabin. The equation demonstrates that room volume and sound absorption are important determinants of acoustic behavior. A large interior space with relatively low sound absorption may produce a longer reverberation time, whereas the introduction of sound-absorbing materials can reduce the persistence of reflected sound. However, the Sabine model is an approximation whose accuracy depends on assumptions concerning the acoustic field and absorption distribution. Actual mosque interiors may exhibit frequency-dependent absorption, non-uniform sound distribution, and complex reflection patterns that require more detailed acoustic assessment (Kuttruff, 2016; Long, 2006).

This relationship can be illustrated through a hypothetical mosque interior with a volume of 5,000 m^3 and an equivalent sound absorption area of 400 m^2 sabin. Applying the Sabine equation produces an estimated reverberation time of approximately 2.01 seconds. If the equivalent absorption area increases to 800 m^2 sabin, the estimated reverberation time decreases to approximately 1.01 seconds. This comparison demonstrates the influence of sound absorption on the persistence of reflected sound. However, these values are theoretical illustrations rather than measurements obtained from an actual mosque. In practical situations, the presence of worshippers, carpet materials, wall finishes, ceiling configurations, and frequency-dependent acoustic properties may produce different results. Therefore, the relationship between dome architecture and acoustic performance should be interpreted through the interaction of multiple variables rather than through a single geometrical characteristic.

Empirical investigations of mosque acoustics provide further support for this interpretation. Prodi and Marsilio (2003) examined the influence of domed ceilings on reverberation through a scale-model study of a mosque. Their investigation demonstrated that the acoustic effects of a dome involve the interaction between its internal volume and the surrounding room, indicating that the dome cannot be treated as an acoustically independent component. Kassim et al. (2014) subsequently investigated the acoustic characteristics of a mosque with a pyramidal dome using computer simulation. Their findings indicated that changes in dome angle and height influenced reverberation time and speech clarity, with steeper pyramidal configurations producing poorer acoustic clarity under the conditions examined. These findings are significant because they demonstrate that architectural geometry influences

not only the distribution of structural forces but also the behavior of sound within enclosed spaces.

Further evidence is provided by Eran et al. (2022), who investigated reverberation time in the Makassar Grand Mosque using acoustic simulation. Their research examined the spatial distribution of reverberation and demonstrated the importance of considering room geometry and acoustic characteristics in evaluating worship environments. Similarly, Eldien (2023) investigated four dome configurations—saucer, drum, onion, and pointed—using ODEON acoustic simulation and in-situ measurements. The study found that dome configuration influenced reverberation characteristics and that saucer and pointed forms demonstrated favorable acoustic performance in the particular building examined. Importantly, the findings also emphasized that acoustic performance varies according to building dimensions and architectural characteristics. These studies collectively establish that the relationship between dome geometry and acoustic quality is context-dependent and requires case-specific examination (Eldien, 2023; Eran et al., 2022; Kassim et al., 2014; Prodi & Marsilio, 2003).

Another acoustic phenomenon relevant to curved architectural surfaces is the *whispering gallery effect*. This phenomenon occurs when sound waves are guided or reflected along curved surfaces in ways that allow sound to travel between particular locations. However, its occurrence depends on the geometry of the surface, the positions of the sound source and receiver, the frequency of the sound, and the reflective characteristics of the material. It should therefore not be assumed that every mosque dome produces this phenomenon. In addition, resonance may occur when the acoustic characteristics of a room reinforce particular frequencies, potentially creating uneven sound distribution. These phenomena offer opportunities to examine the relationship between sound reflection, resonance, frequency, and spatial geometry. More importantly, they demonstrate that acoustic behavior in mosque interiors involves several interconnected mechanisms rather than reverberation alone.

The relationship between structural geometry and architectural acoustics reveals an important conceptual characteristic of mosque architecture: a single cultural object can embody different physical systems that can be investigated through complementary scientific perspectives. Structural mechanics explains how the dome maintains stability and transfers loads, whereas architectural acoustics explains how its spatial configuration influences sound propagation and reflection. Although these domains involve different physical quantities and analytical procedures, both are influenced by geometric characteristics and material properties. Their integration provides a broader understanding of mosque architecture as a multidimensional physical environment. This interpretation also creates an opportunity to

expand ethnophysical inquiry beyond identifying isolated physical concepts within cultural objects toward examining the interaction between multiple scientific principles within a single architectural system.

From the perspective of physics education, these findings provide a basis for transforming mosque architecture into a contextual learning resource. Students can investigate dome configurations through geometric observation, construct simplified structural models, and examine the relationship between curvature and force distribution. They can also explore sound reflection, compare the acoustic characteristics of different spaces, and calculate theoretical reverberation time using room-volume and absorption data. Such activities connect mathematical reasoning with observable physical phenomena and encourage students to recognize the relevance of physics in their surrounding environments. Research on ethnophysics-based educational resources has similarly demonstrated the potential of cultural objects and architectural heritage as contexts for developing scientific understanding (Fakhruddin et al., 2025; Faizah et al., 2025; Rohadi et al., 2025).

Ultimately, the analysis establishes that mosque dome architecture contains two complementary dimensions of physical knowledge: structural geometry and acoustic behavior. The former provides a context for understanding curvature, force distribution, and static equilibrium, while the latter offers opportunities to investigate sound reflection, resonance, and reverberation. Their integration constitutes the scientific foundation for understanding mosque architecture as an ethnophysical learning resource. However, the educational potential of these phenomena depends on how they are transformed into meaningful learning experiences rather than simply presented as architectural facts. This consideration provides the basis for the next discussion, which develops a mosque-based ethnophysics learning framework integrating physical exploration, cultural knowledge, and Islamic educational values.

Towards a Mosque-Based Ethnophysics Learning Framework: Integrating Physics Concepts and Islamic Educational Values

The proposed framework is not presented as an already validated instructional model. Rather, it is a conceptual contribution derived from the synthesis of architectural physics, ethnophysics, contextual learning, and Islamic educational perspectives. This distinction is essential to maintaining methodological consistency with the literature-based research design.

The central argument is that mosque architecture can function as a pedagogical environment in which students move from recognizing cultural objects to investigating physical phenomena, constructing scientific explanations, and developing reflective understandings of Islamic values.

The development of the Mosque-Based Ethnophysics Learning Framework (MELF)

begins with the recognition that scientific knowledge becomes more meaningful when it is connected to the cultural environments in which students live. Conventional physics instruction frequently introduces concepts through standardized examples and mathematical representations, whereas culturally contextualized learning provides opportunities to reconstruct scientific knowledge through familiar objects and experiences. Aikenhead and Jegede (1999) explain that students' cultural backgrounds influence the ways in which they interpret and negotiate formal scientific knowledge. Similarly, Moll et al. (1992) emphasize the educational significance of knowledge developed within families and communities as a resource for classroom learning. These perspectives establish an important foundation for positioning mosque architecture as an educational resource rather than merely an illustrative object in physics instruction.

In this framework, mosque architecture functions as the initial cultural context through which students encounter scientific concepts. The dome, interior space, supporting structures, and architectural materials represent observable features that can be investigated through scientific inquiry. This approach is consistent with the ethnophysics perspective, which recognizes that physical principles are embedded in cultural artifacts and practices. Mashoko (2022) argues that incorporating indigenous artifacts into physics curricula can help students understand science as a culturally situated form of knowledge. Similarly, Faizah et al. (2025) and Fakhruddin et al. (2025) demonstrate how cultural practices and traditional technologies can be transformed into contextual physics learning resources. Consequently, the proposed framework extends this pedagogical orientation to Islamic architectural heritage by connecting the physical characteristics of mosque domes with structured learning experiences.

However, the educational transformation of mosque architecture requires more than identifying physical concepts within its structures. The framework proposes a systematic relationship between cultural observation, scientific investigation, conceptual explanation, and reflective interpretation. Students are not expected to accept architectural phenomena as scientific facts merely because they are associated with religious buildings. Instead, they are encouraged to investigate the phenomena using established scientific principles, mathematical representations, and appropriate evidence. This distinction is important because cultural familiarity provides the context for learning, whereas scientific reasoning provides the means of examining and explaining physical phenomena. The relationship between contextual experience and formal scientific understanding is therefore central to the proposed pedagogical construction (Aikenhead & Jegede, 1999; Snively & Corsiglia, 2001).

A further dimension of MELF concerns the integration of Islamic educational values.

Islamic education recognizes that the development of knowledge should not be separated from ethical awareness, intellectual responsibility, and spiritual reflection. Abdullah (2014) proposes an interconnected perspective on religion, science, and culture, emphasizing the importance of dialogue between different domains of knowledge. In the context of mosque-based physics learning, the concept of *tawazun* can provide a reflective perspective on structural balance, while *tafakkur* encourages students to contemplate the order and complexity of architectural and physical phenomena. The value of *ihsan* can also be introduced through scientific accuracy, responsibility, and careful observation. These relationships should be understood as pedagogical and ethical connections rather than claims that Qur'anic verses directly establish physical equations.

This integration requires a clear distinction between scientific explanation and religious reflection. Physical phenomena must be explained through scientific theories, mathematical relationships, and observable evidence. Islamic values, meanwhile, provide an additional interpretive dimension that encourages students to consider the ethical and spiritual significance of knowledge. Recent research on Islamic values in science instruction has identified the importance of connecting scientific competencies with scientific attitudes, moral responsibility, and religious character (Prayogo et al., 2026). Therefore, MELF proposes an educational approach in which scientific understanding and spiritual reflection complement one another without eliminating their respective epistemological characteristics.

Structural Components and Pedagogical Mechanisms of MELF

Based on the preceding analysis, MELF is proposed as a four-component pedagogical framework consisting of cultural recognition, scientific exploration, conceptual reconstruction, and Islamic value reflection. These components are designed as an interconnected learning process rather than independent instructional activities. Each component addresses a particular dimension of learning while contributing to the development of an integrated understanding of mosque architecture as a physical, cultural, and educational environment.

Table 2. Structural Components of the Mosque-Based Ethnophysics Learning Framework (MELF)

Component	Learning mechanism	Expected educational contribution
Cultural recognition	Observing mosque domes, architectural forms, and interior spaces	Cultural awareness and contextual understanding
Scientific	Investigating geometry, force	Scientific inquiry and

exploration	distribution, sound reflection, and reverberation	observational skills
Conceptual reconstruction	Connecting observations with equations, models, and established physics principles	Conceptual understanding and scientific reasoning
Islamic value reflection	Reflecting on *tawazun*, *tafakkur*, and *ihsan* in relation to scientific inquiry	Ethical awareness and spiritual reflection

Source: Authors' conceptual synthesis based on the literature reviewed.

The first component, cultural recognition, establishes the relationship between students' existing experiences and the scientific subject being investigated. Teachers introduce mosque architecture through photographs, architectural drawings, direct observation, or visits to nearby mosques. Students identify dome configurations, supporting structures, interior surfaces, and spatial characteristics. The purpose is to activate prior knowledge and establish a meaningful context for subsequent scientific investigation. This orientation is consistent with culturally responsive learning, which emphasizes the importance of connecting formal instruction with students' cultural experiences (Moll et al., 1992; Snively & Corsiglia, 2001).

The second component, scientific exploration, transforms cultural observation into systematic investigation. Students examine the mechanical and acoustic characteristics of mosque architecture through guided activities. For structural geometry, they can construct simplified dome models and investigate the relationship between curvature and load distribution. For acoustics, they can compare sound reflection in different spaces, observe the effects of interior materials, and investigate reverberation using simplified measurements. Teachers must distinguish between classroom models and actual architectural behavior so that students do not generalize simplified experimental findings to complex buildings without sufficient evidence. This component reflects the principles of contextualized ethnoscience instruction, in which local artifacts provide meaningful entry points for scientific inquiry (Nurussaniah, 2024; Andriani & Amalia, 2026).

The third component, conceptual reconstruction, enables students to translate their observations into formal physics knowledge. At this stage, the teacher connects structural observations with static equilibrium, geometric calculations, and mechanical forces, while acoustic observations are interpreted through wave reflection, absorption, resonance, and reverberation time. Students are encouraged to explain observed phenomena using scientific terminology, mathematical representations, and evidence-based reasoning. The purpose is not to

replace formal physics instruction with cultural narratives, but to use cultural contexts as a bridge toward more rigorous scientific understanding. Research on ethnophysics-based contextual learning supports the relevance of this approach for connecting cultural experiences with physics concepts and learning outcomes (Faizah et al., 2025; Fakhruddin et al., 2025).

The fourth component, Islamic value reflection, establishes an ethical and spiritual dimension within the learning process. Students reflect on the relationship between structural balance and *tawazun*, scientific observation and *tafakkur*, and accuracy in investigation and *ihsan*. These connections encourage students to understand scientific inquiry as an intellectual activity accompanied by responsibility, humility, and appreciation of creation. The integration must remain reflective rather than reductionist: the Qur'an provides spiritual guidance and ethical meaning, while physical explanations remain grounded in scientific evidence. This distinction is consistent with the interconnected approach to religion, science, and culture proposed by Abdullah (2014).

The four components can be implemented through a learning sequence in which each stage generates the foundation for the next. Assessment should consequently address more than students' ability to reproduce formulas. It should also examine their ability to identify physical phenomena, formulate scientific explanations, interpret evidence, and demonstrate responsible reflection. Teachers may employ observation sheets, conceptual questions, simplified experimental reports, group discussions, and reflective assignments. Such assessment would allow the proposed framework to accommodate cognitive, scientific-process, cultural, and ethical dimensions of learning. Recent studies on contextual physics education and the integration of Islamic values support the importance of connecting scientific understanding with broader student competencies (Nurussaniah, 2024; Prayogo et al., 2026).

Importantly, MELF should be understood as a proposed conceptual framework rather than a standardized instructional model with established effectiveness. Its contribution lies in organizing the relationship between cultural architecture, scientific investigation, formal physics knowledge, and Islamic educational values into a coherent pedagogical structure. This framework provides a theoretical foundation for developing teaching materials, student worksheets, contextual experiments, and future empirical investigations. Its practical applicability and educational effectiveness will require subsequent validation involving physics teachers, educational experts, and students in relevant learning environments.

Ultimately, the proposed framework expands the educational function of mosque architecture by positioning it as a meeting point between cultural heritage, scientific knowledge, and Islamic educational philosophy. Through MELF, the study advances an approach in which

students do not merely learn physics through examples taken from their surroundings, but investigate how scientific principles operate within culturally meaningful environments. This perspective offers a potential contribution to the development of physics education that is scientifically rigorous, culturally responsive, and spiritually reflective.

CONCLUSION

This study demonstrates that mosque dome architecture offers a meaningful contextual resource for integrating physics education with Islamic cultural and intellectual perspectives. Through an ethnophysical analysis, the dome can be understood not merely as an architectural element, but as a physical system in which geometric configurations, structural equilibrium, force distribution, sound reflection, resonance, and reverberation interact. These phenomena provide opportunities to connect abstract physics principles with tangible structures that students encounter in their cultural and religious environments. In particular, the relationship between dome geometry and structural behavior illustrates the application of static equilibrium, while the acoustic characteristics of mosque interiors provide a practical context for exploring sound propagation and reverberation.

Building on these findings, this study proposes the Mosque-Based Ethnophysics Learning Framework (MELF), comprising four interconnected stages: Cultural Recognition, Scientific Exploration, Conceptual Reconstruction, and Islamic Value Reflection. The framework positions mosque architecture as a starting point for scientific inquiry, enabling students to identify physical phenomena, investigate their underlying principles, reconstruct scientific concepts, and reflect on the broader values embedded in Islamic architectural traditions. Values such as *tawazun* (balance), *tafakkur* (reflective contemplation), and *ihsan* (excellence) are incorporated as ethical and spiritual dimensions of learning, rather than as substitutes for scientific explanations or empirical evidence. Accordingly, MELF offers a conceptual approach to connecting scientific literacy, cultural awareness, and Islamic educational values within physics instruction.

Nevertheless, this study is based on a literature-oriented analysis and conceptual synthesis; therefore, it does not establish the empirical effectiveness of MELF in improving students' learning outcomes. The proposed framework requires further investigation through classroom implementation, teacher and student engagement, and systematic assessment of its pedagogical outcomes. Future research should also incorporate direct acoustic measurements, structural observations, and comparisons of different mosque dome configurations to strengthen the connection between architectural phenomena and physics instruction. Such investigations

would help determine the framework's applicability across different educational levels and architectural contexts. Ultimately, this study argues that Islamic architectural heritage should not be treated merely as a historical or aesthetic legacy, but can also serve as an intellectually productive learning environment through which students develop scientific understanding while appreciating the cultural and spiritual dimensions of their surroundings.

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ALMUSTOFA: Journal of Islamic Studies and Research
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