

Expanding STEAM through Heritage and Social Sciences: A Framework for Innovation and Cultural Sustainability

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Chapter Highlights

This chapter highlights a culturally grounded and interdisciplinary STEAM+S framework that integrates heritage, theory, and practice to foster meaningful, future-oriented learning experiences.

- Heritage-Based STEAM+S Framework – Expands traditional STEAM by integrating the social sciences, positioning heritage, culture, and identity as core dimensions of interdisciplinary learning.
- Theoretical Foundations – Grounds the framework in constructivist and sociocultural theory, enriched by design thinking and creative thinking, to support authentic, learner-centred, and culturally meaningful learning experiences.
- Cultural Contextualization through Defensive Architecture – Utilizes Omani forts, castles, and towers as culturally rich contexts, transforming abstract disciplinary knowledge into real-world, meaningful applications.
- Interdisciplinary Integration – Connects science, technology, engineering, arts, mathematics, and social sciences to promote higher-order thinking, problem-solving, innovation, and creativity.
- Educational and Pedagogical Implications – Provides a roadmap for curriculum design through project-based and inquiry-driven learning, while redefining the teacher's role as a facilitator, mentor, and co-learner.

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Introduction

The rapid pace of scientific advances, technological innovations, and knowledge breakthroughs has created new challenges that demand innovative solutions. Education must, therefore, prepare learners with the competencies and skills that are essential for the twenty-first century, moving beyond rote memorization toward authentic, applied learning. In this context, STEAM education has emerged as a powerful interdisciplinary approach for cultivating creativity, critical thinking, problem-solving, and innovation (Perignat & Katz, 2019; Siekmann & Korbel, 2016).

Internationally, STEAM has gained recognition for its role in addressing global economic and technological needs. It emphasizes not only strengthening teachers' capacity to teach across disciplines but also motivating students to pursue STEAM-related fields (Bureau of International Education, 2015). Defined as the integration of science, technology, engineering, arts, and mathematics, STEAM connects academic content with real-world contexts in ways that foster discovery and deeper understanding (Perignat & Katz, 2019). Scholars further describe STEAM as an umbrella framework that bridges disciplinary knowledge with societal productivity, identity, and community life (Mengmeng et al., 2019; Shahat & Al-Balushi, 2023).

The theoretical foundations of STEAM are rooted in constructivist and sociocultural perspectives, which emphasize the importance of authentic tasks, collaboration, and cultural context in knowledge construction (Fosnot, 2013; Vygotsky, 1978; Mengmeng et al., 2019). Research confirms that STEAM enhances achievement in science, mathematics, technology, and the arts while also nurturing life skills, ecological literacy, and motivation for lifelong learning (Beghetto & Kaufman, 2014; Pertiwi et al., 2024). Within this paradigm, the teacher's role shifts from being a transmitter of knowledge to a facilitator of inquiry and collaboration (Al-Balushi et al., 2022, 2025b; Ambusaidi et al., 2022).

Building on this foundation, the present study proposes a heritage-based extension of STEAM (STEAM+S) that incorporates the social sciences as a central dimension. Specifically, it situates defensive architecture—including castles, forts, and walls—as a culturally authentic context through which learners can engage with science, mathematics, technology, engineering, and the arts, while also exploring history, sociology, and identity. Heritage architecture serves not only as a record of societal practices but also as a reservoir of scientific, artistic, and technological knowledge shaped by environmental, political, and cultural factors (Al-Maamari, 2020, 2022).

Within this framework, design thinking is employed as a structured, iterative process that fosters problem-solving, innovation, and collaboration (Nagai & Noguchi, 2003; Razzouk & Shute, 2012; Simon, 1996). Complementing it, creative thinking equips learners with the fluency, flexibility, originality, and elaboration needed to generate meaningful solutions (Beghetto & Kaufman, 2014; Guilford, 1967; Torrance, 1974). Together, these two thinking paradigms transform heritage-based learning into a dynamic platform for cultivating twenty-first-century skills.

Accordingly, this chapter situates STEAM education within a heritage-based, interdisciplinary model that highlights defensive architecture as an entry point for integrating the sciences, arts, mathematics, and social sciences. By doing so, it underscores how STEAM+S, design thinking, and creative thinking can converge to equip learners with innovative, future-oriented skills while simultaneously strengthening cultural identity and societal sustainability (Al-Hushani, 2019; Oman Vision 2040, 2019).

Rationale of this study

The Sultanate of Oman is distinguished by its rich heritage of defensive architecture, including castles, forts, towers, and protective walls. Recognizing their cultural and historical significance, the Ministry of Heritage and Culture has invested in the restoration of major sites through systematic scientific processes that combine documentation, archaeological excavation, traditional restoration methods, regular maintenance, and carefully planned modern adaptations carried out in ways that preserve architectural authenticity. These structures—some dating back more than three millennia—serve not only as monuments of the past but also as enduring symbols of Oman's distinct urban identity in the face of contemporary economic, social, and cultural transformations (Al-Hushani, 2019; Oman Vision 2040, 2019).

The educational value of defensive architecture lies in its potential to cultivate diverse forms of thinking. By analysing how these structures reflect environmental adaptation, engineering ingenuity, artistic expression, and cultural values, students can engage in authentic learning experiences that foster critical, creative, and design thinking. Such learning aligns with Oman's national educational goals, which emphasize inquiry, reflection, cultural awareness, and problem-solving, as well as with Oman Vision 2040, which prioritizes the development of future skills within a globally competitive, yet culturally grounded, workforce (Al-Balushi et al., 2022; Ambusaidi et al., 2022).

In today's knowledge society, education must move beyond the transmission of facts to equip learners with the skills, independence, and adaptability needed to navigate twenty-first-century challenges (Fosnot, 2013; Vygotsky, 1978). Scholars have underscored the importance of nurturing creative and design thinking as foundational capacities for innovation and resilience (Beghetto & Kaufman, 2014; Guilford, 1967; Nagai & Noguchi, 2003; Razzouk & Shute, 2012; Torrance, 1974). Parallel research has also highlighted the value of STEAM integration in linking disciplines, developing life skills, and fostering both ecological literacy and innovation (Perignat & Katz, 2019; Mengmeng et al., 2019; Shahat & Al-Balushi, 2023).

Against this backdrop, the present study introduces a heritage-based STEAM+S framework, where the "S" represents the social sciences. By utilizing defensive architecture as the entry point for interdisciplinary learning, the study aims to demonstrate how cultural identity and modern educational needs can converge to foster design and creative thinking skills essential for preparing Omani learners for the future, while also offering a model with global applicability.

Literature Review and Theoretical Framework

Global Perspectives on STEAM Education

Global literature demonstrates that STEAM has emerged as a powerful interdisciplinary model designed to equip learners with the competencies and dispositions required in the twenty-first century. By integrating science, technology, engineering, arts, and mathematics into a cohesive framework, STEAM promotes creativity, critical thinking, and problem-solving skills that are increasingly demanded in contemporary societies (Perignat & Katz, 2019; Siekmann & Korbel, 2016). International organizations have emphasized the importance of STEAM in preparing students for innovation-driven economies while enhancing teachers' pedagogical capacities for interdisciplinary instruction (Bureau of International Education, 2015).

Empirical studies across contexts provide evidence of STEAM's effectiveness in developing both cognitive and affective outcomes. For example, research confirms that STEAM-based instruction enhances students' critical thinking, creativity, and motivation across multiple disciplines and grade levels (Beghetto & Kaufman, 2014; Pertiwi et al., 2024). Similarly, Mengmeng et al. (2019) emphasize the importance of sociocultural approaches to STEAM, which embed learning in authentic, collaborative contexts. These findings underscore the adaptability of STEAM across various educational stages and disciplines, affirming its potential to

enhance higher-order thinking and learner engagement.

Despite these promising outcomes, the review reveals that most studies focus heavily on the applied sciences and mathematics, with limited attention to identity-related domains such as heritage and culture. This represents a notable gap in the global discourse. Current implementations often overlook the historical and cultural dimensions that have long shaped scientific and technological achievements. For instance, the Egyptian pyramids were not only feats of engineering, mathematics, and artistry but also expressions of cultural and religious values. Similarly, The Great Wall of China reflects both engineering ingenuity and sociopolitical imperatives, while Islamic fortified castles demonstrate the integration of environmental adaptation, architecture, and societal needs.

Building on this insight, the present study proposes an extended model—STEAM+S (Social Sciences/Heritage)—to bridge the applied sciences with cultural and identity-oriented dimensions. The model recognizes that history and culture are not peripheral but rather central forces shaping how science, technology, engineering, arts, and mathematics are conceived, developed, and applied. By integrating heritage and identity into STEAM education, learners experience an enriched interdisciplinary approach that connects them to their cultural context while also developing design thinking and creative problem-solving capacities (Razzouk & Shute, 2012; Nagai & Noguchi, 2003; Torrance, 1974).

This perspective is particularly relevant in Oman, where defensive architecture such as forts, castles, and towers stands as a living testament to the intersection of technological ingenuity, environmental adaptation, and cultural identity (Al-Balushi et al., 2022; Ambusaidi et al., 2022). By situating STEAM education within this heritage-based framework, the study not only addresses the underexplored intersection of STEAM and the social sciences but also contributes to the national priorities of Oman Vision 2040 – strengthening identity and citizenship while preparing learners with the future-ready skills needed in a globally competitive society (Oman Vision 2040, 2019).

Integration of Social Sciences in STEAM

While the global literature has widely emphasized the integration of science, technology, engineering, arts, and mathematics, comparatively little attention has been devoted to incorporating the social sciences as an explicit dimension of STEAM. Yet, education is not solely a technical endeavour; it

is also inherently cultural, historical, and societal. By excluding heritage, history, and social studies, conventional STEAM approaches risk overlooking the broader contexts that both shape and give meaning to scientific and technological advancements.

Recent scholarship highlights the importance of incorporating sociocultural dimensions into STEAM pedagogy. Perignat and Katz (2019) argue that true interdisciplinarity necessitates moving beyond disciplinary silos to incorporate real-world contexts, particularly those grounded in culture and community. Similarly, Siekmann and Korbel (2016) highlight that STEAM has evolved as an umbrella framework—one that should encompass not only technical learning but also initiatives related to citizenship, national productivity, and social responsibility. These insights provide a theoretical basis for extending STEAM to include the social sciences as a sixth dimension, thereby broadening its scope and relevance.

The case for such integration becomes especially evident when examining historical achievements. Monumental structures such as the Egyptian pyramids, the Hanging Gardens of Babylon, and the Great Wall of China demonstrate how social, political, religious, and cultural motivations directly influenced scientific, mathematical, and engineering innovations. In the Omani context, defensive architecture including forts, castles, and towers embodies not only technological ingenuity but also cultural identity, spiritual values, and community resilience (Al-Balushi et al., 2022; Ambusaidi et al., 2022). These examples illustrate that science and engineering cannot be meaningfully separated from their cultural and societal drivers.

Positioning heritage and history as integral dimensions within STEAM—what this study refers to as STEAM+S offers a richer and more holistic model of education. The framework situates learning at the intersection of disciplinary knowledge and socio-cultural identity, allowing learners to engage with authentic contexts that develop both technical competencies and civic understanding. In practice, this enables students to acquire twenty-first-century skills, such as critical thinking, design thinking, and creativity, while simultaneously fostering an appreciation of heritage, cultural identity, and civic responsibility (Razzouk & Shute, 2012; Nagai & Noguchi, 2003).

In Oman, this integration aligns closely with the national priorities outlined in Oman Vision 2040, which emphasize strengthening identity, citizenship, and cultural sustainability alongside innovation and global competitiveness (Oman Vision 2040, 2019). Thus, the STEAM+S framework

provides dual benefits: it enhances learners' problem-solving and creative capacities while embedding these competencies within a culturally grounded, socially responsive model. This positions STEAM+S not only as an educational innovation but also as a strategic response to national development goals and a contribution to the global discourse on interdisciplinary, heritage-based education.

Heritage and Education

Cultural heritage represents a vital dimension of education, serving not only as a record of human achievement but also as a foundation for developing learners' sense of identity, belonging, and citizenship. Heritage encompasses both tangible elements, such as architecture, monuments, and artifacts, and intangible aspects, including traditions, values, and collective memory. From an educational perspective, heritage provides authentic, real-world entry points that connect students to their cultural heritage while also fostering essential twenty-first-century skills. This vision aligns with Omani educational priorities, which emphasize preparing learners for innovation-driven societies while maintaining cultural sustainability (Al-Hushani, 2019; Al-Balushi et al., 2022; Ambusaidi et al., 2022). At the theoretical level, constructivist and sociocultural perspectives reinforce the value of heritage contexts, highlighting that authentic, situated experiences play a central role in shaping meaningful learning (Fosnot, 2013; Vygotsky, 1978).

Globally, heritage education has been recognized as a powerful means of cultivating civic identity and global citizenship. UNESCO (2018) emphasizes that engaging learners in the exploration of historical sites, cultural practices, and intangible traditions equips them not only with factual knowledge but also with the ability to critically reflect on the relationships between the past and the present. This pedagogical approach enables education to move beyond the transmission of abstract knowledge, anchoring learning in contexts that are meaningful, situated, and socially relevant.

In the Omani context, defensive architecture including forts, castles, and towers constitutes a distinctive dimension of the nation's cultural heritage. These structures are not merely military relics. If you'd like to maintain a parallel structure, change to: "but also embody of accumulated expertise in engineering, construction, environmental adaptation, and artistic expression, while also reflecting broader social, political, and religious realities (Al-Balushi et al., 2022; Ambusaidi et al., 2022). For example, the design of thick fortress walls demonstrates mathematical precision and

adaptation to climatic conditions, while intricate decorative motifs carved into doors and ceilings reflect the aesthetic values and cultural identity of the communities that built them. As such, defensive architecture offers a multidisciplinary resource that integrates science, technology, engineering, arts, mathematics, and social sciences.

The educational potential of heritage-based contexts lies in their ability to foster both cognitive and affective outcomes. Cognitively, they challenge learners to analyse structures, interpret their functions, and connect them with scientific and mathematical principles. Affectively, they strengthen cultural pride, identity, and a sense of continuity with the past. This dual capacity aligns with contemporary calls for education that balances skill development with identity formation, a need made increasingly urgent by the forces of globalization (Perignat & Katz, 2019; Mengmeng et al., 2019).

While prior STEAM research has largely focused on applied sciences and mathematics, the integration of heritage and identity remains underexplored. By positioning defensive architecture as the entry point for the proposed STEAM+S framework, this study advances a new direction in educational research and practice one that embeds design and creative thinking within culturally authentic contexts. Such an approach ensures that learners not only acquire transferable twenty-first century skills but also deepen their appreciation of heritage, in line with Oman Vision 2040's emphasis on identity, citizenship, and cultural sustainability (Oman Vision 2040, 2019).

Theoretical Framework: The STEAM + S Model

Constructivist Learning Theory

Constructivist learning theory posits that learners actively construct their own knowledge by engaging with authentic, meaningful tasks rather than passively receiving information. Learning occurs when individuals interact with real-world contexts that challenge prior conceptions, prompting them to reorganize and extend their understanding (Piaget, 1972; Fosnot, 2013). In this paradigm, the role of the teacher shifts from being a transmitter of knowledge to a designer of learning environments that stimulate inquiry, exploration, and reflection (Shahat & Al Amri, 2023).

Within the STEAM+S framework, constructivism provides the foundational lens for connecting disciplinary knowledge with cultural and social realities. Defensive architecture—such as Omani forts, castles, and towers—functions as a real-world context that unites science, technology, engineering, arts, mathematics, and social sciences. For example, when investigating the

structural design of a fort, learners may calculate wall thicknesses to explore geometry, apply engineering principles to test stability, analyse materials for climate adaptation, study decorative arts for cultural symbolism, and reflect on the historical and social motivations behind architectural choices (Ambusaidi et al., 2022; Al-Balushi et al., 2022).

This approach shifts learning from abstract concepts to practical applications. Instead of viewing geometry as a set of isolated formulas, students engage in tasks such as measuring arches or simulating construction methods to understand the concept of structural stability. Rather than treating history as a sequence of memorized dates, learners analyse how political, social, and religious forces influenced design decisions. Through these activities, students actively construct meaning, linking disciplinary knowledge to lived experiences and cultural identity (Perignat & Katz, 2019; Vygotsky, 1978).

In the Omani context, where defensive architecture symbolizes resilience, ingenuity, and cultural continuity, the constructivist application of STEAM+S enables learners to achieve both cognitive outcomes (problem-solving, design thinking, creative thinking) and affective outcomes (identity formation, cultural pride, and social responsibility). Projects such as building scale models of forts, conducting digital simulations, or analysing restoration practices not only enhance interdisciplinary knowledge but also highlight the relevance of this knowledge to learners' own society and heritage (Shahat & Al-Balushi, 2023; Ambusaidi et al., 2022).

Thus, constructivist learning theory validates the use of heritage-based defensive architecture as a pedagogical tool within the STEAM+S model, positioning learners as active participants in knowledge construction while grounding their learning in culturally authentic contexts that bridge the global and the local (Oman Vision 2040, 2019).

Sociocultural Theory

Sociocultural theory, grounded in the work of Vygotsky (1978), emphasizes that learning is inherently social and shaped by cultural and historical contexts. Knowledge is constructed through interaction with others, mediated by language, tools, and shared cultural practices. Central to this perspective is the zone of proximal development (ZPD), which illustrates how learners can achieve higher levels of understanding through guided support, collaboration, and social interaction.

Within the STEAM+S framework, sociocultural theory reinforces the view that education is not only cognitive but also cultural and contextual. Defensive architecture, a distinct feature of Omani heritage, serves as a cultural tool that facilitates learning. When students engage with forts, castles, or towers, they are not simply examining physical structures- they are interacting with artifacts that embody the collective history, values, and social identity of their communities (Al-Balushi et al., 2022; Ambusaidi et al., 2022). This engagement situates learning within meaningful cultural contexts, bridging the past and present while preparing students for future societal roles.

Collaborative learning activities- such as group projects to design scale models of heritage buildings, role-playing debates about their historical significance, or community-based restoration initiatives- illustrate the sociocultural dimension of STEAM+S. Through these tasks, learners co-construct knowledge, negotiate meaning, and develop shared understandings that integrate scientific inquiry with social and cultural awareness (Mengmeng, Li, & Chen, 2019; Perignat & Katz, 2019). Teachers, in turn, act as facilitators and mediators, scaffolding learning by connecting disciplinary concepts to cultural narratives and lived experiences (Shahat & Al Amri, 2023).

The integration of the social sciences as a sixth dimension ensures that STEAM education extends beyond technical mastery to cultivate identity, citizenship, and cultural continuity. In alignment with Oman Vision 2040 (2019), sociocultural theory provides the theoretical justification for embedding heritage into interdisciplinary learning. It validates the idea that students' intellectual growth is inseparable from their social environments, traditions, and community practices.

Thus, sociocultural theory strengthens the STEAM+S framework by positioning heritage-based defensive architecture not merely as content, but as a mediational tool-a bridge between learners' cultural identity and their acquisition of twenty-first-century skills.

Design Thinking Framework

Design thinking is an iterative human-centred process that emphasizes creativity, problem-solving, and innovation. Rooted in the practices of designers and engineers, it has been widely adapted into education as a framework to help learners approach complex challenges with empathy, experimentation, and reflection (Razzouk & Shute, 2012; Nagai & Noguchi,

2003). The process typically unfolds through cyclical stages empathize, define, ideate, prototype, and test each of which encourages learners to generate, refine, and evaluate solutions collaboratively (Simon, 1996).

Within the STEAM+S model, design thinking serves as the methodological engine that enables students to engage actively with heritage-based contexts, such as Omani defensive architecture. For instance, when learners investigate how a fort was designed to balance structural stability, environmental adaptation, and defence against threats, they begin by empathizing with the needs of past communities. They then define the architectural problem, ideate possible solutions, and prototype models using modern materials or digital simulations before testing and refining their designs. This cyclical process mirrors the historical challenges faced by architects while simultaneously fostering twenty-first century competencies (Shahat & Al Amri, 2023).

Design thinking also bridges the technical and cultural dimensions of STEAM+S. By integrating engineering principles with artistic creativity and social understanding, students learn to balance function and aesthetics, utility and symbolism. For example, a classroom project might ask learners to redesign a fort's gate to be both structurally secure and reflective of Omani cultural motifs. Such a task bridges the connection between mathematics and engineering, on the one hand, and art and heritage, on the other, positioning design as a site where culture and innovation converge (Perignat & Katz, 2019).

Moreover, design thinking aligns closely with constructivist and sociocultural theories by positioning learners as active creators of knowledge in authentic, collaborative contexts. It fosters both divergent and convergent thinking, enabling students to explore multiple possibilities before narrowing them down to feasible solutions. Importantly, design thinking cultivates resilience, as learners come to view setbacks and failures as opportunities for iteration and growth rather than as endpoints (Beghetto & Kaufman, 2014).

In the Omani context, embedding design thinking into STEAM+S not only enhances problem-solving and innovation but also strengthens learners' sense of cultural continuity. By reimagining heritage architecture through design challenges, students develop both technical competence and cultural literacy embodying the dual goals of Oman Vision 2040 (2019): global competitiveness and cultural sustainability.

Thus, the design thinking framework operationalizes STEAM+S,

transforming heritage-based learning into a dynamic process of inquiry, innovation, and cultural engagement.

Creative Thinking Framework

Creative thinking is widely recognized as one of the essential competencies of the twenty-first century, enabling learners to generate novel, valuable, and contextually relevant solutions to complex problems (Beghetto & Kaufman, 2014; Perignat & Katz, 2019). Foundational work by Guilford (1967) and Torrance (1974) identified its core dimensions as *fluency* (generating many ideas), *flexibility* (shifting perspectives), *originality* (producing unique ideas), and *elaboration* (refining and extending ideas). More recent perspectives extend these dimensions, framing creative thinking as a dynamic process that integrates imagination, critical analysis, and practical application within real-world contexts (Beghetto & Kaufman, 2014).

Within the STEAM+S framework, creative thinking serves as a cognitive driver that transforms disciplinary knowledge into innovative outcomes. Heritage-based contexts such as Omani defensive architecture provide fertile ground for cultivating creativity. For instance, analysing the geometric patterns of castle walls or the artistic carvings on wooden doors allows learners to experiment with combining mathematical precision, engineering functionality, and cultural symbolism. These tasks stimulate divergent thinking while grounding creativity in authentic cultural narratives (Al-Balushi et al., 2022; Ambusaidi, et al., 2022).

Creativity in this model extends beyond the production of new artifacts to include the reinterpretation of heritage. When learners reimagine how forts could be adapted for modern community use while retaining their historical identity, they engage in acts of creativity that bridge tradition and innovation. This duality resonates with Oman Vision 2040 (2019), which emphasizes cultural sustainability while also cultivating future-ready competencies such as problem-solving, innovation, and adaptability.

Moreover, creative thinking complements design thinking within STEAM+S. While design thinking provides structured stages for addressing problems (Razzouk & Shute, 2012; Nagai & Noguchi, 2003), creative thinking enriches each stage with imaginative possibilities and novel perspectives. Together, they foster an educational environment in which learners can move beyond conventional solutions, embrace experimentation, and develop confidence in their ability to contribute new ideas (Beghetto & Kaufman, 2014).

Classroom applications may include brainstorming sessions, creative prototyping, artistic reinterpretations of heritage motifs, and collaborative projects where students generate multiple solutions to shared problems. Through these activities, learners develop not only technical and artistic competencies but also openness, resilience, and aesthetic appreciation qualities that are essential for innovation in a globalized, interconnected world (Shahat & Al-Balushi, 2023).

In sum, the creative thinking framework strengthens STEAM+S by equipping learners to transform interdisciplinary integration into original, socially and culturally meaningful contributions. By linking creativity with heritage, students are encouraged to value their cultural identity while cultivating the imaginative capacities required to navigate and shape the future.

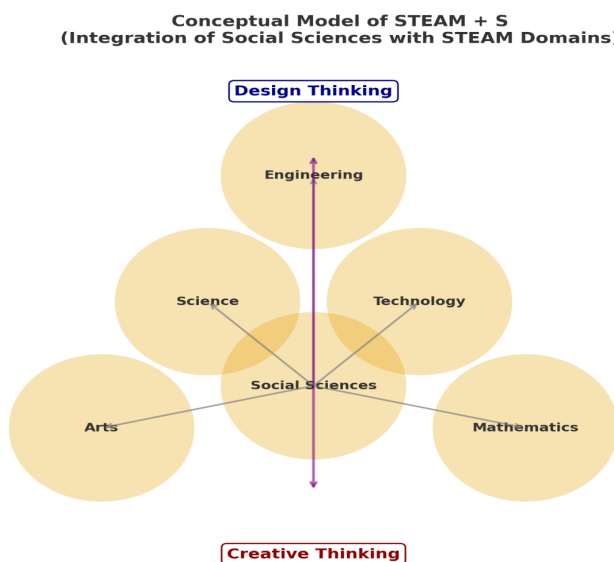


Figure 1. Conceptual Model of STEAM+S

The Heritage-Based STEAM+S Framework

Conceptualization of the Model

The Heritage-Based STEAM+S framework is conceptualized around the principle that cultural heritage particularly defensive architecture can serve as an authentic entry point for interdisciplinary learning. Castles,

forts, towers, and protective walls are not only historical landmarks but also living examples of how scientific, technological, engineering, artistic, mathematical, and social dimensions converge to meet societal needs. By situating learning within these culturally grounded contexts, the model enables students to connect abstract disciplinary knowledge to real-world applications that are both meaningful and identity-sustaining (Al-Balushi et al., 2022).

The framework draws on interdisciplinary integration across six domains, highlighting how defensive architecture embodies the full spectrum of STEAM+S:

- **Science:** Understanding the natural materials used in construction, their geological sources, and how environmental conditions such as climate and erosion influence structural durability (Ambusaidi et al., 2022).
- **Technology:** Exploring both traditional and modern construction methods, restoration techniques, and innovative approaches to heritage preservation (Al-Hushani, 2019).
- **Engineering:** Analysing structural design, stability, and defensive functionality, including how architectural forms adapted to terrain, warfare, and community protection (Shahat & Al Amri, 2023).
- **Arts:** Investigating the aesthetic and symbolic dimensions of architecture, including decorative motifs, calligraphy, woodwork, and designs that reflect cultural identity (Perignat & Katz, 2019).
- **Mathematics:** Applying geometry, measurement, proportionality, and spatial reasoning in examining architectural layouts, wall thickness, arches, and towers (Guilford, 1967; Torrance, 1974).
- **Social Sciences:** Examining the historical, cultural, and societal forces that shaped architectural decisions, including security needs, governance structures, religious influence, and community identity (Al-Maamari, 2020, 2022; Oman Vision 2040, 2019).

This conceptualization underscores that defensive architecture is not merely a subject of historical interest but a multidimensional learning resource. Through the STEAM+S framework, learners apply disciplinary knowledge, engage in design and creative thinking (Beghetto & Kaufman, 2014), and strengthen their cultural identity and citizenship awareness by situating learning in authentic Omani heritage. In doing so, the framework aligns with Oman Vision 2040's priorities of sustaining cultural identity while equipping learners with innovation-oriented, globally competitive skills (Oman Vision 2040, 2019).

Application of the Framework

The application of the Heritage-Based STEAM+S framework lies in transforming cultural landmarks into living laboratories for interdisciplinary learning. This approach enables students to bridge theoretical knowledge with hands-on exploration, while simultaneously cultivating cultural identity, design thinking, and creative problem-solving skills (Ambusaidi, et al. 2022, Shahat et al., 2025a). By embedding learning in culturally authentic contexts, the model aligns with both constructivist and sociocultural perspectives, which emphasize the importance of meaningful, situated tasks in building knowledge (Fosnot, 2013; Vygotsky, 1978).

Interdisciplinary Applications

- **Science:** Students investigate the chemical and physical properties of materials such as stones, clays, and woods, analysing how they contributed to the durability of forts and castles. They also examine environmental adaptations, including insulation and natural ventilation systems that reflect traditional ecological knowledge (Ambusaidi et al., 2022; Aldayri et al., 2023).
- **Technology:** Learners compare historical construction tools and methods with modern techniques such as 3D scanning and digital modelling, while also studying preservation practices that integrate traditional materials with contemporary technologies (Al-Hushani, 2019; Shahat et al., 2024a,b,c,d). This highlights how heritage preservation embodies the intersection of tradition and innovation.
- **Engineering:** By analysing wall thickness, arches, and towers, students explore the principles of stability and defensive functionality. Using simulations or prototypes, they test redesign scenarios to enhance resilience while preserving the authenticity of heritage. Such tasks foster engineering design competencies critical to STEM education (Shahat, et al., 2022; Shahat et al., 2024d).
- **Arts:** Students engage with decorative motifs, carvings, calligraphy, and inscriptions, interpreting their symbolic meanings and cultural significance. They then produce new designs inspired by Omani heritage, demonstrating how artistic creativity and identity are interwoven within architectural contexts (Perignat & Katz, 2019; Beghetto & Kaufman, 2014).
- **Mathematics:** Learners apply geometry, measurement, proportionality, and spatial reasoning by calculating angles, dimensions, and layouts of forts and castles. Activities include creating scale models or digital simulations, linking abstract mathematical principles to real-world architectural challenges

(Piaget, 1972; Guilford, 1967; Torrance, 1974).

- Social Sciences: Students investigate historical narratives, sociological influences, and cultural values embedded in defensive architecture, situating heritage within broader contexts of security, governance, and community identity (Al-Maamari, 2020, 2022; Oman Vision 2040, 2019). This dimension underscores the social and cultural embeddedness of knowledge, aligning with global perspectives on citizenship and sustainability (Bureau of International Education, 2015; Mengmeng, Li, & Chen, 2019).

Classroom Examples

The application of the Heritage-Based STEAM+S framework in classroom practice can be illustrated through a range of interdisciplinary units that merge disciplinary knowledge with cultural and historical contexts. These examples demonstrate how heritage can function as a living laboratory, supporting both cognitive and affective learning outcomes (Fosnot, 2013; Vygotsky, 1978; Shahat & Al-Balushi, 2023).

The Geometry and Symbolism of Forts

This unit could begin with a site visit (physical or virtual) to a heritage site. Students would measure structures (mathematics), analyse stability and load-bearing principles (engineering), test building materials (science), explore cultural motifs and symbolism (arts), and examine historical accounts (social sciences). The project might culminate in scaled prototypes, 3D-printed reconstructions, or digital simulations, accompanied by student presentations that explicitly connect technical design to cultural meaning. Such tasks foster higher-order thinking and identity formation while situating abstract concepts in real-world contexts (Guilford, 1967; Torrance, 1974; Ambusaidi, Shahat, & Al Musawi, 2022).

Sustainability Lessons from Ancient Water Systems

Students investigate aflaj systems in Oman or Roman aqueducts, examining water flow and chemistry (science), calculating capacity, ratios, and geometry (mathematics), analysing engineering strategies for channelling water across terrain (engineering), and discussing the sociocultural role of these systems in sustaining communities (social sciences). Learners could design modern adaptations using renewable energy or digital monitoring technologies (technology), while producing artistic maps and visualizations of historical water networks (arts). This example highlights the global transferability of STEAM+S and its potential to address contemporary sustainability challenges

(Aldayri et al., 2023; Perignat & Katz, 2019).

Mathematics in Islamic Geometric Art

Here, learners analyse tessellations and geometric patterns in fort decorations (mathematics), investigate the tools and techniques used in carving and design (technology), connect motifs to architectural principles of balance and symmetry (engineering), and reflect on their cultural and symbolic significance (social sciences). Students then create their own designs using both traditional tools and digital design software, merging artistic creativity with mathematical precision. This task develops both technical skills and aesthetic appreciation, in line with calls for integrating creativity into STEAM pedagogy (Beghetto & Kaufman, 2014; Shahat & Al-Balushi, 2023).

Defensive Architecture and Community Life

This unit involves students investigating how forts functioned not only as military structures but also as centres of governance, trade, and culture. Learners explore the chemistry and durability of construction materials (science), model fort defences under different scenarios (engineering), recreate market scenes or storytelling traditions linked to forts (arts), and analyse historical records about community life (social sciences). Techniques such as digital storytelling, augmented reality reconstructions, or dramatizations can be used to present findings, thereby highlighting the human dimension of heritage alongside its technical achievements (Al-Maamari, 2020, 2022; Oman Vision 2040, 2019).

Teacher Interviews and Insights

An exploratory qualitative design was adopted to examine Omani teachers' perceptions of the Heritage-Based STEAM+S framework. Twenty social studies teachers were purposively selected to ensure diversity in years of teaching experience, grade levels taught, and prior exposure to innovative pedagogy. The sample represented both basic and post-basic education, thereby reflecting the broader structure of Oman's educational system (Al-Balushi, et al., 2022).

A semi-structured interview protocol was developed and informed by prior research on STEM/STEAM integration in social studies and science education (Shahat, 2022; Shahat et al., 2024c). The protocol was designed to capture teachers' perspectives across six domains: their knowledge and awareness of STEM/STEAM, the applicability of such approaches in social

studies, perceived challenges, pedagogical practices and strategies, relevant STEM/STEAM elements, and examples of added value. Each interview, conducted in Arabic, lasted between 30 and 45 minutes and was audio-recorded with participants' consent before being transcribed for analysis.

Thematic analysis was employed to analyse the data, guided by a systematic coding process (Creswell, 2019; Field, 2009). During open coding, descriptive codes were generated directly from the data, including phrases such as *"heritage relevance," "curriculum overload," "digital tools,"* and *"identity pride."* Axial coding followed, clustering related codes into broader categories for instance, curriculum overload and time pressure were merged into the category of systemic constraints. Selective coding then allowed these categories to be linked to the overarching research questions, with systemic constraints and training needs, for example, converging into the core theme of implementation challenges. The coding process adopted a hybrid approach, combining deductive strategies based on the interview protocol with inductive strategies that captured emergent insights, such as alignment with Oman Vision 2040 (2019).

NVivo 12 software was used to facilitate the coding process, enabling the organization, retrieval, and comparison of data across cases. The software also supported the creation of coding matrices that made it possible to trace how descriptive codes clustered into categories and themes, thereby enhancing analytic transparency. To ensure consistency, two transcripts were manually double-coded and then cross-checked within NVivo, thereby strengthening intercoder agreement and methodological rigor.

Several strategies were employed to ensure the study's trustworthiness. Credibility was achieved through member checks, whereby three participating teachers reviewed the interpretations to validate their accuracy and authenticity. Dependability was maintained by ensuring coding consistency through the double-coding process. Confirmability was supported by keeping a detailed audit trail of coding decisions, ensuring transparency and accountability in the analytic process. Finally, transferability was addressed by providing thick description of the Omani heritage-based educational context, allowing readers to assess the applicability of findings to other educational and cultural settings (Fosnot, 2013; Vygotsky, 1978).

The coding process generated five overarching themes, each supported by categories, illustrative codes, and insights from the interviewed teachers. The first theme, knowledge and awareness of STEM/STEAM, revealed varied

levels of teacher understanding. Some participants demonstrated only a limited conception, with one explaining, “STEM is only math and science” (T3). Others displayed moderate awareness, recognizing its interdisciplinary nature and describing it as “integrated disciplines” (T11). A smaller group articulated a more advanced perspective, emphasizing the inclusion of cultural and artistic dimensions, as highlighted by one teacher who noted, “STEAM must include heritage and arts” (T16). Overall, awareness ranged widely, with only a minority explicitly identifying the heritage dimension.

The second theme, applicability in social studies, reflected a strong consensus among participants that the subject provides fertile ground for STEM integration. Geography was repeatedly identified as a natural entry point, with one teacher commenting, “GIS and mapping make lessons more interactive” (T7). Heritage contexts, such as the aflaj irrigation systems, were also seen as opportunities to merge engineering and environmental studies, as another participant explained: “We can explain aflaj irrigation as both a historical and engineering achievement” (T14). Others noted that demography provides a valuable domain for integration, using “population statistics to show links between math and society” (T9).

The third theme, challenges in implementation, highlighted several systemic barriers. Teachers frequently mentioned the problem of time and curriculum overload, with one stating, “The syllabus is too dense for projects” (T2). Others pointed to resource shortages, particularly in relation to digital tools, remarking that, “We don’t have VR or AR tools to make heritage come alive” (T18). A lack of professional development was another recurring concern, as one participant admitted, “There are no workshops on how to apply STEM in social studies” (T5). In addition, teachers raised the issue of assessment misalignment, with one observing, “Exams don’t fit projects, so we avoid them” (T12).

The fourth theme, practices and strategies, revealed that many teachers are already incorporating STEM-related approaches, albeit often unintentionally. Some described the use of digital tools, such as “Google Earth to teach geography” (T8), while others shared examples of project-based learning, including “building fort models” (T10) and “team projects where each student had a role” (T4). Teachers also referred to simulations of real-world problems, such as “disaster simulations to explain natural hazards” (T15). These accounts suggest that even in the absence of structured training, teachers are experimenting with approaches aligned with STEAM+S principles.

Finally, the fifth theme, cultural identity and citizenship, emerged as a particularly strong area of emphasis. Teachers repeatedly emphasized that heritage-based learning instils pride and strengthens identity. As one participant expressed, “Students felt proud of forts because they realized our ancestors used engineering long before modern science” (T6). Others linked heritage learning with broader national priorities, stating, “Heritage aligns with sustainability goals and Oman Vision 2040” (T13). Collectively, teachers emphasized that embedding heritage into STEAM+S not only deepens identity formation but also equips students with future-ready skills, thereby bridging tradition with innovation. Table 1 provides an illustrative sample of the coding process used in this exploratory qualitative study, showing how descriptive codes were clustered into categories and broader themes.

Table 1. Coding Process from Teacher Interviews

Theme	Categories	Example Codes	Illustrative Quotes (Teacher Codes)
Knowledge & Awareness	Limited, Moderate, Advanced awareness	“STEM is only math and science”; “Integrated disciplines”; “STEAM must include heritage and arts”	“STEM is only math and science” (T3); “Integrated disciplines” (T11); “STEAM must include heritage and arts” (T16)
Applicability	Geography, Heritage, Demography	“GIS and mapping”; “afaj irrigation”; “population statistics”	“GIS and mapping make lessons interactive” (T7); “Afaj irrigation is both historical and engineering” (T14)
Challenges	Curriculum overload, Resource gaps, Training needs, Assessment misalignment	“Syllabus too dense”; “No VR/AR tools”; “No workshops”; “Exams don’t fit projects”	“The syllabus is too dense for projects” (T2); “We don’t have VR/AR tools” (T18)
Practices & Strategies	Tech use, Project-based learning, Collaboration, Simulations	“Google Earth”; “Fort models”; “Team projects”; “Disaster simulations”	“Google Earth to teach geography” (T8); “Students loved building fort models” (T10)
Identity & Citizenship	Pride in heritage, Oman Vision 2040, Heritage as tool	“Proud of forts”; “Ancestors used engineering”; “Heritage aligns with sustainability”	“Students felt proud of forts” (T6); “Heritage aligns with Oman Vision 2040” (T13)

The coding analysis confirms that teachers view STEAM+S as a pedagogically powerful model. Results support the theoretical foundations:

- Constructivism: Students learn more deeply when tasks are authentic (e.g., fort models, aflaj studies).
- Sociocultural theory: "Heritage contexts mediate learning, linking cultural identity to disciplinary knowledge.
- Design and creative thinking: Teachers saw project-based, iterative tasks as opportunities for innovation and resilience.

The findings also highlight the dual promise and challenge of STEAM+S. While teachers acknowledged its capacity to enhance engagement and cultural identity, they also underscored the need for institutional support including professional training, digital infrastructure, and curriculum flexibility. These findings align closely with Oman Vision 2040's dual emphasis on innovation and cultural sustainability.

Expected Outcomes

The Heritage-Based STEAM+S framework is designed to generate outcomes across three interconnected domains cognitive, affective, and societal. Findings from the semi-structured teacher interviews reinforced these projected outcomes, providing empirical validation and practical grounding for the model. From a cognitive perspective, the framework promotes higher-order thinking by engaging learners in authentic architectural challenges that demand problem-solving, analysis, and critical reasoning. Teachers noted that tasks such as modelling forts or analysing aflaj systems required students to integrate knowledge from multiple disciplines and apply it in practical ways. Design thinking was also fostered, as learners engaged in prototyping, testing, and iterative redesign, thereby cultivating systematic and innovative approaches to problem-solving (Razzouk & Shute, 2012; Nagai & Noguchi, 2003). In addition, creative thinking was strengthened through activities that encouraged fluency, flexibility, and originality in reimagining heritage structures and motifs (Guilford, 1967; Torrance, 1974; Beghetto & Kaufman, 2014). Teachers further reported that heritage-based approaches enhanced disciplinary mastery, deepening students' understanding of science, mathematics, engineering, and the arts by situating abstract concepts within culturally meaningful contexts (Pertiwi et al., 2024).

The affective outcomes were equally significant. Teachers emphasized that heritage-based lessons fostered stronger cultural identity and pride, as students developed a deeper appreciation for Omani heritage,

reinforcing their sense of belonging (Al-Maamari, 2020, 2022). Motivation and engagement also increased, with teachers observing that students approached projects with greater enthusiasm and persistence compared to traditional lessons. Moreover, collaborative group tasks nurtured dispositions of teamwork, empathy, and communication, creating a learning environment where interpersonal skills were developed alongside academic competencies (Perignat & Katz, 2019; Vygotsky, 1978).

At the societal level, the Heritage-Based STEAM+S framework was recognized as aligning closely with the aspirations of Oman Vision 2040, which emphasizes innovation, identity, and sustainability (Oman Vision 2040, 2019). Teachers viewed it as a bridge between cultural sustainability and the acquisition of future-ready skills, enabling students to contribute to both national identity and global competitiveness (Al-Hushani, 2019; Ambusaidi et al., 2022). They also highlighted the potential for heritage-based projects to enhance community engagement by forging stronger ties between schools and local communities, as students interacted with cultural resources beyond the classroom (Cushner, 1992). Ultimately, the framework was seen as equipping learners with the dual capacities of technical expertise and cultural awareness, preparing them to navigate global challenges while remaining grounded in their heritage.

Taken together, the five emergent themes awareness, applicability, challenges, strategies, and identity map directly onto the three outcome domains projected in the Heritage-Based STEAM+S framework. Awareness reflects the cognitive domain, as it influences how teachers and students conceptualize interdisciplinary knowledge. Applicability extends into the societal domain, highlighting how social studies can embed heritage in authentic, community-relevant learning (Shahat & Al-Balushi, 2023). Challenges reveal barriers that must be addressed to achieve both cognitive and societal outcomes, particularly in relation to curriculum design and policy (Al-Mazrouei & Olayan, 2020). Strategies connect to cognitive outcomes, such as design and creative thinking, while also supporting affective outcomes, including collaboration, motivation, and engagement (Siekmann & Korbel, 2016). Finally, identity strongly resonates with the affective domain, reinforcing cultural pride and belonging, while simultaneously linking to the societal domain through its alignment with Oman Vision 2040 (2019). This mapping demonstrates how teachers' perspectives empirically validate the framework's potential to enrich cognitive, affective, and societal learning outcomes.

In summary, the Heritage-Based STEAM+S framework broadens conventional understandings of STEAM education by integrating heritage, culture, and identity into interdisciplinary learning. The teacher interview findings validate its potential to enrich cognitive, affective, and societal domains, while also underscoring the need for targeted professional development and access to digital resources (Al-Balushi, Al-Harthi, & Shahat, 2022). By positioning defensive architecture as both content and context, the framework ensures that learners acquire twenty-first century skills while sustaining national identity, thereby contributing simultaneously to innovation and cultural continuity.

Methodological Implications

The Heritage-Based STEAM+S framework presents significant methodological implications for curriculum design, instructional practice, and the evolving role of teachers in twenty-first-century education. By integrating science, technology, engineering, arts, mathematics, and social sciences through the authentic lens of defensive architecture, the framework demonstrates how culturally grounded, interdisciplinary approaches can transform both teaching and learning (Shahat & Al-Balushi, 2023; Ambusaidi et al., 2022).

Guiding Curriculum Design

This framework offers curriculum developers a model for integrating heritage-based themes into interdisciplinary units, connecting abstract disciplinary knowledge with real-world cultural contexts. Instead of organizing content in isolation, curricula can be designed around authentic problems and projects drawn from heritage architecture. For instance, units on measurement and geometry can be linked to fort design, while social studies and arts can emphasize the symbolism and historical significance of defensive structures. Such integration ensures coherence across subjects and fosters higher-order thinking, problem-solving, design, and creative skills. Importantly, it aligns with constructivist principles, enabling learners to construct meaning from authentic cultural contexts (Piaget, 1972; Fosnot, 2013), and with sociocultural theory, situating learning in socially and historically significant practices (Vygotsky, 1978).

Prior research in Oman has underscored the importance of embedding culturally authentic contexts into curriculum frameworks. For example, Shahat and Al-Amri (2023) highlighted the strengths and shortcomings of integrating STEM into science teacher preparation, while Shahat et al.

(2024a) emphasized the role of STEM-integrated experiences in enhancing elementary teacher preparation. These insights reinforce the methodological contribution of the STEAM+S model as a bridge between disciplinary content and cultural identity.

Integration into School Programs

The framework naturally supports project-based and inquiry-driven learning, where students collaborate on meaningful, open-ended tasks (Perignat & Katz, 2019). Practical applications include:

- **Project-Based Units:** Students design and test scale models of forts, analyse their structural stability, and present adaptations for modern use while preserving cultural authenticity.
- **Inquiry Tasks:** Learners explore critical questions, such as “Why were forts built in specific locations?” or “*How did climate and materials influence their construction?*”
- **Virtual and Augmented Simulations:** Technology can provide immersive experiences that allow students to explore reconstructed forts, experiment with structural modifications, or visualize historical scenarios (Shahat et al., 2024d).

Embedding such approaches into school programs exposes students to rich interdisciplinary content while also cultivating transferable life skills such as collaboration, cultural awareness, digital literacy, and creative problem-solving (Pertiwi et al., 2024; Al-Hushani, 2019).

Role of Teachers as Facilitators

The successful implementation of the Heritage-Based STEAM+S framework depends on a pedagogical shift in the teacher’s role—from knowledge transmitter to facilitator, designer, and mentor. Teachers are positioned as:

- **Designers of learning environments,** structuring tasks that connect disciplinary concepts to heritage contexts.
- **Curators of cultural and digital resources,** guiding students in exploring authentic heritage materials.
- **Scaffolders of inquiry,** posing critical questions and supporting iterative processes of design and creativity.
- **Assessors of broader competencies,** evaluating not only content mastery but also skills such as teamwork, innovation, identity formation, and cultural appreciation (Shahat et al., 2025b, c).

This reconceptualization of the teacher’s role resonates with design

thinking pedagogy, where iterative processes of ideation, prototyping, and testing are embedded in classroom practice (Nagai & Noguchi, 2003; Razzouk & Shute, 2012), and with creative thinking frameworks, which encourage flexibility, originality, and elaboration in student responses (Guilford, 1967; Torrance, 1974; Beghetto & Kaufman, 2014). By adopting this stance, teachers create dynamic classrooms where learners are empowered to explore, innovate, and construct knowledge through culturally authentic, interdisciplinary experiences.

Contribution and Implications

This study contributes to educational research and practice on three interconnected levels theoretical, practical, and policy-related by advancing the scope of STEAM education and situating it within a heritage-based paradigm.

Theoretical Contributions

At the theoretical level, the study extends existing STEAM models by introducing the Heritage-Based STEAM+S framework, where the “S” represents social sciences with an emphasis on heritage, identity, and culture. Much of the global literature has traditionally positioned STEAM as a bridge between applied sciences and real-world problem-solving (Perignat & Katz, 2019; Siekmann & Korb, 2016), but has often neglected the historical and cultural dimensions that shape knowledge construction. By embedding defensive architecture as an entry point for learning, the model situates constructivist (Piaget, 1972; Fosnot, 2013), sociocultural (Vygotsky, 1978; Al-Maamari, 2020, 2022), design thinking (Razzouk & Shute, 2012; Nagai & Noguchi, 2003), and creative thinking theories (Guilford, 1967; Torrance, 1974; Beghetto & Kaufman, 2014) within a single holistic framework. This integration positions cultural heritage not as peripheral but as central to interdisciplinary learning, thereby redefining the theoretical boundaries of STEAM education (Shahat & Al-Balushi, 2023).

Practical Contributions

On a practical level, the study offers educators and curriculum developers a heritage-based model for designing culturally relevant, interdisciplinary units. In the Omani context, defensive architecture forts, aflaj systems, and castles presents a compelling platform for project-based learning, inquiry-driven tasks, and immersive digital simulations that engage students in authentic exploration across disciplines (Ambusaidi, et al., 2022).

The model also offers scalable applications beyond Oman. For example:

- Roman aqueducts link engineering, mathematics, and environmental science.
- Islamic geometric art integrates mathematics, design, and cultural studies.
- Indigenous dwellings connect sustainability, anthropology, and technology.

Such examples illustrate that the Heritage-Based STEAM+S framework is a replicable and adaptable approach that educators worldwide can adopt to merge academic content with cultural relevance. By doing so, it bridges local traditions with global competencies, offering a roadmap for innovative and identity-affirming teaching practices (Al-Balushi et al., 2022). Embedding these global parallels highlights that the model is not limited to Oman but can be applied across various cultural and educational settings internationally.

Policy Contributions

At the policy level, the study aligns closely with the priorities outlined in Oman Vision 2040 (2019), which emphasize cultural sustainability, identity formation, and the development of future-ready citizens. The framework offers policymakers a concrete model for integrating heritage into national curricula in a manner that safeguards cultural continuity while promoting innovation and global competitiveness (Al-Hushani, 2019; Shahat et al., 2024c).

Moreover, the framework has international relevance. In a global context where nations grapple with balancing economic modernization and cultural preservation, the Heritage-Based STEAM+S framework provides a policy-relevant blueprint. It aligns with global agendas such as UNESCO's Education for Sustainable Development goals, which advocate for educational approaches that integrate sustainability, cultural awareness, and global citizenship (Bureau of International Education, 2015).

To conclude, the Heritage-Based STEAM+S framework makes a multi-level contribution. Theoretically, it redefines STEAM to include heritage and identity as essential dimensions of learning. Practically, it equips educators with strategies and exemplars for culturally relevant, interdisciplinary integration. At the policy level, it offers a model for aligning national priorities with global educational agendas. Together, these contributions highlight the transformative potential of the framework to reposition heritage from a static legacy into a dynamic resource for innovation, sustainability, and lifelong learning – both within Oman and across diverse international contexts.

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RETHINKING STEM EDUCATION

Theoretical and Sociocultural Frameworks

Rethinking STEM Education: Theoretical and Sociocultural Frameworks presents a concise yet comprehensive exploration of STEM education as an interdisciplinary and socially embedded field. Grounded in key theoretical perspectives such as constructivism, radical constructivism, cognitive load theory, and sociocultural theory, this edited volume connects foundational learning theories with contemporary instructional practices, curriculum design, and assessment approaches. The book adopts a holistic perspective by positioning mathematics as a core integrative component of STEM, examining technology as a transformative force in learning and assessment, and emphasizing inclusive and formative evaluation practices aligned with 21st-century skills. Beyond pedagogy, it situates STEM education within broader sociocultural, ethical, and ecological contexts, addressing themes such as community engagement, responsible innovation, environmental sustainability, and culturally grounded STEAM+S frameworks. Designed for researchers, educators, and policymakers, this volume offers a theoretically informed and socially responsive perspective on rethinking STEM education for a rapidly changing world.