A Museum-Based STEAM Approach to Science Learning, Artistic Skills, and Cultural Heritage

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Abstract: The aim of this study is to investigate the effectiveness of museum-integrated STEAM (Science, Technology, Engineering, Art, and Mathematics) activities in enhancing middle school students' conceptual understanding of science, developing artistic skills, and increasing awareness of the recognition and preservation of cultural heritage within out-of-school learning environments. The research focuses on STEAM-based educational practices implemented in museum settings as interdisciplinary learning environments that connect scientific concepts with artistic expression and cultural heritage through Kolb's Learning Theory. A mixed-methods triangulation design was employed to examine both quantitative learning outcomes and qualitative changes in students' learning processes. The study group consisted of 20 eighth-grade students selected through purposive sampling. The implementation involved three structured museum visits: the Naval Museum, Troy Museum, and Ceramic Museum. Quantitative data were collected using a researcher-developed Concept Knowledge Test and the Cultural Heritage Awareness Scale, administered as pre- and post-tests. Qualitative data was obtained through structured observation forms and artistic evaluation forms. Quantitative data were analyzed using SPSS v.25.0, while qualitative data were examined through content analysis. The findings indicate that STEAM-based museum activities positively influenced students' understanding of scientific concepts, enhanced their awareness of cultural heritage conservation, and supported the development of selected artistic skills.

Keyword: STEAM education in museums

INTRODUCTION

Rapid developments in science and technology have reshaped the competencies required for effective participation in modern society, making creative thinking, innovation, and interdisciplinary problem-solving essential skills for 21st-century learners. In this context, STEAM education—integrating science, technology, engineering, art, and mathematics—has gained increasing attention as a pedagogical approach that bridges analytical reasoning with artistic expression, thereby enhancing learners' engagement, creativity, and conceptual understanding (Yakman, 2008; Root-Bernstein, 2015).

As formal education alone may not always provide sufficiently rich experiential learning opportunities, informal learning environments such as museums have emerged as valuable spaces where learners can connect scientific knowledge with cultural and artistic contexts through hands-on exploration (Falk & Dierking, 2006; Behrendt & Franklin, 2014). Museums function not only as repositories of cultural and historical artifacts but also as interdisciplinary learning settings in which students actively construct meaning by interacting with authentic objects that reflect the interconnectedness of science, art, and cultural heritage.

Within this framework, museum-based STEAM activities offer unique potential to foster scientific concept learning and artistic skill development while simultaneously raising awareness of the importance of preserving cultural heritage. However, despite growing interest in STEAM education and museum learning, the existing literature reveals a limited number of empirical studies that address these three educational outcomes—scientific understanding, artistic skills, and cultural heritage awareness—within a single, integrated instructional framework.

This study addresses a globally relevant problem: how informal learning environments such as museums can be effectively transformed into active STEAM learning spaces that support inquiry, creativity, and interdisciplinary thinking. Previous research has highlighted the role of museums in promoting inquiry-based and experiential learning beyond formal classroom contexts (Falk & Dierking, 2013; National Research Council, 2009). Nevertheless, studies also indicate that museums worldwide often struggle to engage learners beyond passive observation (Hein, 1998; Tran, 2007).

In response to this gap, integrating STEAM approaches into museum education has been identified as a promising strategy to promote interdisciplinary learning, creativity, and problem-solving skills in informal learning environments (Henriksen, 2014; Yakman & Lee, 2012). Given that museums across different countries face similar educational challenges, this study proposes a STEAM-based framework that offers an internationally transferable and scalable model adaptable to diverse cultural and educational contexts.

Accordingly, the present study investigates the impact of STEAM activities implemented in three different museums in Çanakkale on eighth-grade students' conceptual understanding of science topics, development of artistic skills, and awareness of cultural heritage. By situating learning within culturally meaningful museum spaces and employing experiential and interdisciplinary practices, this research aims to contribute empirical evidence to the international literature on the educational value of museum-based STEAM environments.

Literature review

STEAM education represents an interdisciplinary framework designed to foster creativity, innovation, and problem solving for real-world contexts. The origins of this approach can be traced to the United States, where a shortage of professionals in STEM fields and students' limited interest in these domains raised national concerns in the early 2000s. As a response, educational reforms aimed to strengthen K–12 instruction through integrated STEM initiatives. The STEM approach has faced criticism due to the exclusion of art and design disciplines, which are essential for adequately fostering creativity. These criticisms are fundamentally based on the question of whether four quantitatively oriented disciplines alone are sufficient to cultivate key competencies such as creativity, innovation, and critical thinking. In response to this issue, Yakman (2008) expanded the scope of the STEM model by integrating the arts and proposed the STEAM approach. The STEAM educational model combines the arts with STEM subjects to enhance students' creativity, engagement, innovation, problem-solving abilities, and other cognitive benefits (Hetland & Winner, 2004; Liao, 2016; NAEA, 2016; Root-Bernstein, 2015). Furthermore, it is considered a contemporary and multidimensional teaching model within literature, as it aims to equip individuals with employability skills such as teamwork, collaboration, communication, and adaptability that are necessary for career development and economic advancement (Colucci-Gray et al., 2017).

Over time, the incorporation of the arts transformed STEM into STEAM, recognizing that creativity and aesthetic thinking are central to innovation and socio-cultural understanding (Henriksen, 2013; Perignat & Katz-Buonincontro, 2018). Globally, several countries have prioritized STEAM; for instance, the Korean Ministry of Education formally adopted it as a national educational policy in 2011 (Anderson, 2021). Research emphasizes that STEAM instruction not only connects five major disciplines but also encourages learners to view knowledge holistically, link scientific reasoning with artistic expression, and develop higher order thinking and design skills (Yakman & Lee, 2012). As Mercin (2019) noted, the inclusion of art addresses the creativity gap in traditional STEM education by enabling students to produce original and meaningful artifacts. Accordingly, the main goal of STEAM education is to equip learners with the capacity to integrate disciplinary knowledge, engage in authentic inquiry, and apply their understanding to solve everyday problems through creative and sustainable solutions.

Recent research has increasingly emphasized the effectiveness of STEAM-based instructional approaches that promote active engagement, creativity, and hands-on learning. Sağat (2019) reported that STEAM-oriented science instruction for fifth-grade gifted students enhanced their creative design abilities, fostered awareness of integrated STEAM learning models, and strengthened their motivation and analytical thinking skills. Similarly, Kwak and Ryu (2016) observed that STEAM research in Korea has primarily focused on science-centered implementations, highlighting the need for more balanced interdisciplinary applications. In a comprehensive review of 44 studies, Perignat and Katz-Buonincontro (2019) revealed a wide range of definitions for STEAM and persistent ambiguities surrounding art-integration pedagogies, although most scholars agreed that STEAM promotes creativity and higher-order thinking. Moreover, previous STEAM practices often lack rigorous assessment mechanisms to evaluate learners' development in creativity, artistic expression, and problem-solving skills. Therefore, in the present study, students' artistic skill improvement was systematically assessed throughout the activities not solely based on the final product using a researcher-developed rubric.

Akbaba (2017) found that teachers perceive the expanding Maker and STEAM movements as beneficial for preparing students for daily life, describing these approaches as purposeful and content rich. Graham and Brouillette (2016), through the San Diego Teaching Artist Project (TAP), demonstrated that art-integrated physics lessons combining dance, drama, music, and visual arts led to significantly higher conceptual understanding and engagement among third- to fifth-grade students compared with traditional instruction. Teachers generally believe that STEAM enhances 21st-century skills such as problem-solving and scientific process abilities while increasing students' interest in science courses (Uğraş, 2017). Inwood and Taylor (2012) argued that art offers alternative learning pathways for students who struggle in cognitively oriented science classes, and Gültekin and Demir (2022) confirmed that art-integrated science activities improve academic achievement, attitudes, and creativity.

Azkın and Çevik (2022) reported statistically significant improvements in students' attitudes toward art following STEAM activities, while Helvacı and Yılmaz (2020) showed that art-centered visual arts instruction under the STEAM framework fostered positive views toward both art and the other STEM disciplines In Taiwan, Tran et al. (2021) developed a STEAM curriculum in which students designed mechanical clock models to study gear mechanisms; post-test analyses showed significant gains in fluency and flexibility dimensions of scientific creativity and also Pereira et al. (2024) reported that STEAM activities involving physical-energy concepts improved students' digital creativity, collaboration, and critical-thinking skills.

Collectively, these findings demonstrate that STEAM-integrated art and science activities not only enhance students' conceptual and academic learning but also nurture creativity, collaboration, and problem-solving key competencies for 21st-century learners. The integration of the arts into STEM education, commonly referred to as STEAM, aims to cultivate creativity, innovation, and holistic skill development among students. Across both international and Turkish contexts, a growing body of literature indicates that the inclusion of artistic processes such as visual design, performance, and creative expression enhances not only scientific understanding but also artistic and aesthetic skill development. Early conceptual works (Yakman & Lee, 2012) positioned STEAM as a transdisciplinary educational paradigm connecting scientific reasoning with artistic creativity. Subsequent empirical research has reinforced this relationship. Guyotte et al. (2015) and Liao (2016) demonstrated that integrating visual arts within science and engineering lessons promotes creative problem solving, design thinking, and expressive communication. Similarly, Henriksen (2013) analyzed exemplary STEM teaching practices and found that when art is deliberately integrated, students demonstrate higher levels of imagination and aesthetic reasoning. A large-scale integrative review by Perignat and Katz-Buonincontro (2019) synthesized more than 80 studies between 2006–2018, confirming that art integration significantly enhances students' creativity, motivation, and artistic expression. Research on STEAM education increasingly highlights the importance of integrating artistic processes into learning environments. Early empirical evidence by Gülhan and Şahin (2018) demonstrated that STEAM activities foster significant improvements in scientific creativity while simultaneously promoting positive attitudes toward art-integrated science learning among 7th-grade students. Similarly, Madenci and Yılmaz (2019) emphasized that embedding artistic skills into STEAM projects not only enhances collaboration but also strengthens students' aesthetic awareness and creative design capabilities. Ozkan and Topsakal (2021) reported that an 11-week STEAM design-based intervention yielded meaningful gains in both figural and verbal creativity, indicating that hands-on design, experimentation, and iterative thinking processes strongly support creativity development. Ulus and Okvuran (2025) corroborated these findings by demonstrating that art-centered STEAM activities lead to significant improvements in students' artistic creativity. Moreover, Filipe et al. (2024) found that integrated STEAM instruction enhances problem-solving and digital creativity skills among high school learners, while also increasing engagement, innovation, and confidence in self-expression through art-embedded STEM tasks such as multimedia design.

Taking together, both national and international findings converge to show that when art is positioned as a core component rather than an auxiliary element, STEAM education promotes higher-order creative outcomes. This body of research underscores that creativity, aesthetic sensitivity, and artistic confidence can be systematically cultivated through instructional models that meaningfully integrate artistic processes into STEAM learning. Art-integrated STEAM education has been shown to contribute not only to the enhancement of creativity and problem-solving skills but also to students' conceptual understanding and academic achievement. Research indicates that when artistic expression and design processes are embedded into STEM learning, students are more likely to engage in divergent thinking and creative risk-taking (Özkan & Topsakal, 2021; Ulus & Okvuran, 2025). Studies focusing on science instruction further demonstrate that STEAM-based interventions help students construct deeper conceptual knowledge and reduce misconceptions through hands-on, interdisciplinary activities (Açıkgöz, 2025; Özkan & Topsakal, 2021). Additionally, STEAM environments foster motivation, collaboration, and engagement, all of which support improvements in academic performance (Amanova et al., 2025; Filipe et al., 2024). Taken together, these findings suggest that incorporating the arts into STEM not only enhances creativity but also strengthens conceptual learning pathways and supports measurable gains in students' academic outcomes.

In contemporary education, learning is no longer confined to the classroom; it can occur in any environment that fosters active engagement and inquiry. Learners are expected to transition from passive recipients of information to active participants who construct knowledge through experience. Museum education offers one of the richest contexts for such experiential learning (Gürkan, 2004). Museums function not only as spaces where historical and cultural artifacts are displayed but also as dynamic institutions of science, culture, and education (Ekiz & Koyuncu, 2020). Within this framework, museum education encompasses exhibitions, objects, and interdisciplinary learning activities designed to engage learners cognitively, emotionally, and physically in accordance with fundamental educational principles (Pereira, et al., 2024; Şahan, 2005).

As institutions that preserve and communicate cultural heritage, museums play a critical role in raising societal awareness about the importance of protecting the material and intangible legacy of humanity (Korkmaz et al., 2019; Külcü, 2015). The recognition, preservation, and transmission of cultural heritage require the active participation of educators and scientists who prepare future generations to value and safeguard such heritage. In Turkey, museum education was formally incorporated into the national curriculum in 2005–2006 following a decision by the Board of Education. The aim was to enable students to explore natural and cultural assets, conduct observations, and engage in hands-on activities that connect museum experiences with curricular content. University-level teacher education programs have also included museum pedagogy as part of their coursework (Karadeniz & Okvuran, 2014).

The recent changes in the national curriculum in our country highlight the importance of inquiry-based and experiential learning strategies, emphasizing the role of informal environments such as museums, science centers, and natural sites in science education (MoNE 2024). Modern museums thus serve not only as repositories of artifacts but also as pedagogical environments where students interact with visual, auditory, and tactile materials, developing perceptual, cognitive, and psychomotor skills (Özrili, 2021). Özrili's study demonstrated that museums, as interdisciplinary learning environments, foster engineering thinking and problem-solving abilities through authentic, hands-on experiences.

Despite this potential, the integration of STEAM-based activities into museum education remains underexplored in literature. Museums, especially science centers and cultural institutions that combine art, history, science, and technology, offer fertile grounds for STEAM-oriented learning. For instance, non-formal learning environments such as science museums have proven effective contexts for STEAM project-based learning, allowing learners to engage in authentic, real-life tasks that foster conceptual understanding, creativity, and motivation (Domenici et al., 2022). In a study adopting STEAM methodology within a museum setting, pre-service teachers designed and implemented chemistry-centered laboratory activities in a science museum, finding that such non-formal contexts significantly enhanced participants' interest, sense of ownership, and understanding of scientific concepts (Domenici et al., 2022). Similarly, research incorporating architecture, arts, culture, and history into mathematics education in a museum learning environment demonstrated how integrating art and real-world context into traditionally abstract subjects can deepen learners' conceptual understanding and support interdisciplinary thinking (El Bedewy et al., 2024). Moreover, children's workshops and interactive exhibits in museums provide opportunities for experiential learning, encouraging exploration, inquiry, and personal meaning-making (Karadeniz-Akdoğan, 2025). These findings suggest that when art, design, science, and culture are woven together in museum-based STEAM experiences, students not only develop creativity and problem-solving skills, but also build stronger conceptual connections and real-world relevance in their learning.

The previous studies, such as Karadeniz and Okvuran (2014) and Kızılay (2021), have examined museum education through teacher-training or early-childhood contexts, often emphasizing drama or creativity rather than science learning. Kolb's (2013) Experiential Learning Theory (ELT) provides a coherent theoretical foundation for interpreting how museum-based STEAM activities foster meaningful learning. ELT defines learning as a cyclical process consisting of concrete experience, reflective observation, abstract conceptualization, and active experimentation. Museum environments naturally embody this cycle: students first engage in concrete experiences by observing and manipulating authentic artifacts (museum objects and cultural items), followed by reflective observation as they discuss and interpret their observations in small groups or guided dialogues. These reflections then lead to abstract conceptualization, where learners connect observations to scientific principles or artistic expressions. Finally, through active experimentation, students transform their insights into creative outputs—designing models, prototypes, or artistic representations that merge science, engineering, and art.

Empirical studies have shown that Kolb's framework effectively explains learning processes within museum-based STEAM contexts. For instance, Kim and Park (2020) demonstrated that experiential cycles embedded in STEAM lessons significantly enhanced elementary students' scientific reasoning and creativity. Tran, Huang, and Hung (2021) applied Kolb's cycle in a museum-based mechanical clock design project and found improvements in fluency and flexibility dimensions of creativity. Similarly, Graham and Brouillette (2016) incorporated Kolb's experiential stages into an arts-integrated physics program (The San Diego Teaching Artist Project), observing higher engagement and conceptual understanding compared to traditional instruction. In the Turkish context, Helvacı and Yılmaz (2020) and Azkın and Çevik (2022) reported that art-centered STEAM activities guided by experiential learning principles fostered more positive attitudes toward both science and art disciplines. These findings indicate that Kolb's cyclical model is not only adaptable across cultural and disciplinary settings but also instrumental in explaining the iterative, hands-on, and reflective nature of STEAM learning.

Within the present study, museum visits and corresponding STEAM activities were explicitly structured around Kolb's learning cycle. Each museum Ceramic Museum, Troy Museum, and Naval Museum provided concrete experiences through authentic cultural artifacts, while post-visit reflections and creative design workshops supported conceptualization and experimentation phases. By situating Kolb's theory in a museum context, this framework highlights how experiential learning not only deepens scientific understanding but also cultivates cultural awareness, creativity, and a personal connection to heritage core aims of integrated STEAM education.

The current study therefore addresses a significant research gap by designing and implementing STEAM activities within museums as out-of-school learning environments to enhance middle school students' understanding of science concepts and their awareness of cultural heritage preservation. Conducted with eighth-grade students in museums followed by related STEAM-based learning modules. The goal was to determine how STEAM practices situated in museum contexts influence students' conceptual understanding, retention of scientific knowledge, and awareness of cultural heritage. By situating science learning within culturally meaningful contexts, this study aims to demonstrate that museum-based STEAM education can simultaneously deepen conceptual understanding and foster cultural heritage awareness. Thus, it contributes to the existing body of research by bridging four underexplored domains: STEAM education, experiential learning, museum-based science teaching and cultural heritage awareness.

Accordingly, the research question guiding this study is: To what extent do museum-based STEAM activities affect eighth-grade students' awareness of cultural heritage, their learning of science concepts and effects of the activities on students' artistic skill development?

METHOD

In line with the research objectives, a mixed-methods design was employed to identify and evaluate changes observed within the participant group throughout the implementation process. Mixed-methods research, as defined by Creswell and Clark (2007), refers to studies that integrate and analyze both quantitative and qualitative data collected under various procedures and designs, often combining the strengths of both paradigms to provide a more comprehensive understanding of the research problem. In this study, qualitative data were utilized alongside quantitative findings to explore the underlying reasons behind statistical outcomes and to generate new strategies or theoretical insights. Accordingly, a convergent parallel mixed design (also referred to as a triangulation design) was adopted. Within this approach, quantitative and qualitative data are collected and analyzed separately, and the results are subsequently merged to provide an integrated interpretation of the findings.

Participants

The study group consisted of 20 eighth-grade students (12–13 years old), including 9 males and 11 females. The participants were selected using a purposive sampling method, which allows the inclusion of individuals who can provide rich, relevant, and diverse data for the research aims. The sample comprised disadvantaged students from a lower socioeconomic background who had not previously visited any of the museums included in the study. The selection of eighth-grade students was based on the alignment between the targeted science learning outcomes and the 8th-grade learning objectives specified in the Science curriculum. Random selection within the purposive sampling group ensured equal opportunity for participation, minimizing sampling bias and enhancing representativeness. According to Creswell and Creswell (2018), probabilistic random sampling methods strengthen internal validity and improve the generalizability of research findings, while Fraenkel, et al. (2019) emphasize that such procedures enhance the study's reliability and accuracy.

Data Collection Instruments

To determine whether the research objectives were achieved, both quantitative and qualitative data collection instruments were employed. Quantitative data was obtained through two main tools.

Cultural Heritage Awareness Scale developed by Demir (2023), administered as a pre-test and post-test to measure students' awareness of cultural heritage. The scale was developed through literature review, student interviews, and expert evaluation to ensure content and face validity. Following a pilot study, the final version consisted of 36 items across three factors, demonstrating acceptable levels of validity and reliability. Science Concept Knowledge Test, 17 items, multiple-choice instrument developed by researchers to assess understanding of key science concepts aligned with the 8th-grade Science curriculum. Initially containing 21 items, the test was refined after expert review by two professors and one associate professor to ensure content validity.

Qualitative data were collected through structured observation forms. The first question of the form, presented in Table 1, was administered prior to the museum visit to assess students' initial expectations. The remaining two questions were designed to enable a deeper exploration of students' learning processes during the activities, focusing on the development of cultural heritage awareness and science concept knowledge. In addition, an artistic evaluation form for assessing the products created in the students' STEAM activities was developed in collaboration with one professor, one associate professor, and one assistant professor from the Faculty of Fine Arts, all of whom are experts in their respective fields. This form was used to obtain qualitative data regarding the positive effects of the activities on students' artistic skills development. The samples of questions and evaluation criteria were given in table 1.

Table 1.
Examples of questions in data tools.

Data Collection Instruments	Examples of questions
Science concept knowledge test	1-In the garden of the Troy Museum, a model of the Trojan Horse stands on four legs. Each leg rests on a metal plate with a different surface area touching the ground. After some time, it was observed that the stones under the narrower plates were more deeply pressed into the ground. Question: Which of the following best explains this situation in terms of solid pressure? A) As the weight increases, the surface area increases and the pressure decreases. B) When the same weight acts on a smaller surface area, the pressure increases. C) As the surface area increases, the pressure increases. D) Pressure depends only on the object's weight and is not affected by surface area.
Cultural Heritage Awareness Scale	* I can recognize important historical places in distant regions around me. * Our culture varies from one region to another. * I can identify which civilizations or states the historical sites in my local area belong to. * I can identify in which provinces or cities important historical artifacts in distant regions are located.
Observation forms	Before activity Question: What are you expecting to learn during today's museum visit? After activity Question: What did you learn in this museum? Question: Which scientific concepts did you explore through this activity?
Artistic skills evaluation form	Relevance to the Theme Overall Design Structure Creativity Time Management Technical Skill Clarity of Presentation

Data Analysis

Quantitative data were analyzed using SPSS version 25.0. Tests for normality and Cronbach's alpha reliability coefficients were first conducted. Depending on the normality results, parametric or non-parametric analyses were applied to examine significant differences between pre- and post-test scores. The level of statistical significance was set at $p < .05$.

Qualitative data was analyzed through content analysis. Student responses from the art-analysis rubrics and reflection forms were open-coded to identify emerging codes, categories, and overarching themes. Each researcher independently conducted the initial coding, after which consensus meetings were held to reconcile differences and refine thematic interpretations. The qualitative findings were then integrated with the quantitative results to produce a comprehensive synthesis of the outcomes, ensuring methodological triangulation and interpretive validity.

Implementation

The implementation phase of the study was designed in alignment with Kolb's Experiential Learning Theory (2013), which conceptualizes learning as a cyclical process of *concrete experience, reflective observation, abstract conceptualization,* and *active* *experimentation*. The activities were organized around the eighth-grade science curriculum (MoNE, 2018), focusing on the units *Physical Events* (Pressure; Simple Machines), *Matter and Its Nature* (Physical and Chemical Changes), and *Energy Transformations and Environmental Science* (Recycling). These units were purposefully selected to correspond with the content and themes of the museums visited, enabling students to experience curriculum outcomes through authentic and interdisciplinary contexts.

1. Concrete Experience: Students participated in three museum visits where they directly observed historical, scientific, and artistic artifacts. Guided discovery and inquiry-based activities such as *"Search and Find"* and *"Who Am I?"* were implemented to encourage exploration and interaction with the exhibits. During these sessions, students worked collaboratively to identify and discuss scientific concepts embedded in the displayed objects, connecting them to everyday phenomena.
2. Reflective Observation: Following each visit, structured reflection sessions were held in which students expressed their impressions and discussed what they had learned. Creative-drama activities were used to help them articulate observations, emotions, and ideas about both science and cultural heritage. These reflective practices allowed students to evaluate their experiences from multiple perspectives, linking scientific principles with cultural narratives.
3. Abstract Conceptualization: In this stage, students synthesize their museum experiences with theoretical knowledge from the curriculum. They analyzed the physical and chemical properties of materials observed in the exhibits and interpreted energy transformation processes and recycling themes considering scientific concepts. Through group discussions and teacher-guided questioning, students reconstructed abstract scientific ideas derived from tangible museum experiences.
4. Active Experimentation: After the museum visits, a series of STEAM-based implementations in Table 2 were conducted to promote the practical application of knowledge. Students designed and created prototypes, artistic models, and experiments that combined elements of science, engineering, and art as shown in figure 1, 2, 3 and 4. These design-based tasks provided opportunities for students to test their ideas, engage in problem-solving, and demonstrate their understanding through hands-on creation. Each STEAM activity thus completed Kolb's experiential cycle, transforming museum visits into integrated learning experiences that fostered both scientific understanding and cultural heritage awareness.

Table 2.
Implemented Activities, Aims and Duration

Name of the Activity	Intended Science Learning Outcomes	Duration
Most Powerful Horse. Troy Horse	*To explore and discover the factors affecting solid pressure through experiments. *To provide examples of how the pressure properties of solids, liquids, and gases are applied in daily life and technology. *To promote awareness of using natural resources efficiently. *To design a research project focused on the sustainable and economical use of resources.	3 hours
Unsinkable ship	*To explore and identify the factors affecting solid pressure through experiments. *To predict and test the variables influencing liquid pressure. *To provide examples of how the pressure properties of solids, liquids, and gases are applied in everyday life and technology. *To design a simple machine that facilitates work in daily life.	3 hours
Create from Ceramic	*To discover through experiments that heating depends on the type, mass, and/or temperature change of a substance. *To explore through experiments that the heat required for a change of state depends on the type and mass of a substance. *To understand that compounds are formed because of chemical reactions.	3 hours

	*To encourage responsible and efficient use of natural resources. *To identify potential problems that may arise from the wasteful use of resources and propose possible solutions.

Figure 1.
Unsinkable ship activity

Figure 2.
Create from Ceramic activity

Figure 3.
Production of ceramic activity

Figure 4.
Production of Unsinkable ship

Limitations of the Study

While Turkish studies in this field have predominantly focused on short-term classroom-based interventions, there remains a clear need for long-term and cross-disciplinary evaluations that can capture the sustained development of artistic skills and their transferability across learning domains. In the present study, this limitation is addressed through the implementation of three distinct museum visits and a series of STEAM-based activities designed according to Kolb's Experiential Learning Theory (2013). Although the study seeks to mitigate the short-term nature of previous research by emphasizing experiential and iterative learning cycles, the scope will nevertheless remain limited to three STEAM activity modules, which will be acknowledged as a methodological constraint of the study.

Ethics, Funding and the Use of Artificial Intelligence

This study was approved by the Ethics Committee of Çanakkale Onsekiz Mart University (Approval No: E-84026528-050.01.04-2300301692). Furthermore, informed consent was obtained from the parents of each participating student. Artificial intelligence support (ChatGPT) was utilized for English language editing during the preparation of the manuscript.

RESULTS

Quantitative measurement scales results

In this part, study learning of science concept and cultural heritage were aware compared by using pre and post test results.

Concept Test (Pre-test and Post-test) Results

Table 3.
The Shapiro–Wilk Normality Test Results for the Concept Test.

	W	p
Pre-test	0.941	0.256
Post-test	0.943	0.269

In table 3, A Shapiro–Wilk test was conducted to examine the normality of the data distribution. The results for the pre-test (W = 0.941, p = .256) and post-test (W = 0.943, p = .269) indicated that the data were normally distributed.

Table 4.
The Reliability Analysis Findings of the Concept Test (Cronbach's Alpha)

Test	Number of Items	Cronbach's Alpha	Standardized Alpha
Pre-test	17	0.555	0.516
Post-test	17	0.565	0.617

The internal consistency of the concept test was assessed using Cronbach's alpha shown in table 4. The coefficients were α = .555 for the pre-test and α = .565 for the post-test, indicating a borderline acceptable level of reliability (George & Mallery, 2003).

Table 5.
The Comparison of Science Concept Test Pre-test and Post-test Scores

n	Mean	SD	t	df	p
Pre-test	0.4471	0.18068			
Post-test	0.6912	0.16885			
Difference (Pre–Post)	-0.24412	0.18865	5.335	16	.000***

The results of the paired-samples t-test revealed that the post-test scores (M = 0.6912, SD = 0.16885) were significantly higher than the pre-test scores (M = 0.4471, SD = 0.18068), t(16) = 5.34, p < .001. This finding (Table 5) indicates that the STEAM activities conducted in the museum significantly improved students' science conceptual understanding.

Cultural Heritage Scale Findings

Table 6.
The Shapiro–Wilk Normality Test Results for the Cultural Heritage Scale

	W	p
Pre-test	0.9297	0.152
Post-test	0.9576	0.498

As shown in Table 6, the Shapiro–Wilk test was performed to assess the normality of the Cultural Heritage Scale data. The pre-test (W = 0.9297, p = .152) and post-test (W = 0.9576, p = .498) results indicated that the data were normally distributed.

Table 7.
The Reliability Results of the Cultural Heritage Scale (Cronbach's Alpha)

Test	Number of Items	Cronbach's Alpha	Standardized Alpha

Pre-test	36	0.908	0.911
Post-test	36	0.820	0.799

As presented in Table 7, the internal consistency of the Cultural Heritage Scale was calculated using Cronbach's alpha. The coefficients were α = .91 for the pre-test and α = .82 for the post-test, indicating high reliability in both administrations.

Table 8.
The results of Comparison of Cultural Heritage Scale Pre-test and Post-test Scores (Paired Samples t-Test).

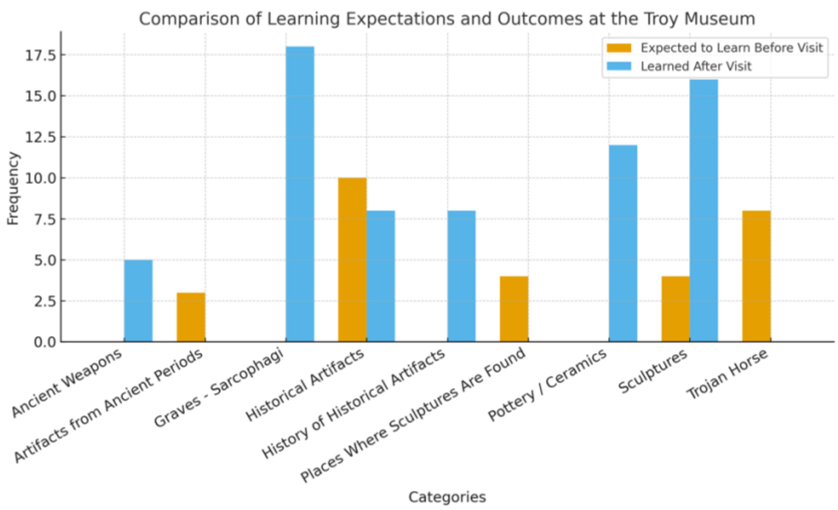
Variable	**n**	**Mean**	**SD**	**t**	**df**	**p**
Pre-test	36	0.5889	0.19387			
Post-test	36	0.7375	0.14946			
Difference (Pre–Post)		-0.14861	0.14417	-6.185	35	.000***

The paired-samples t-test results in Table 8 indicated that the post-test scores (M = 0.7375, SD = 0.14946) were significantly higher than the pre-test scores (M = 0.5889, SD = 0.19387), t (35) = -6.19, $p < .001$. This result demonstrates that students' awareness and understanding of cultural heritage increased significantly after the implementation of the learning activities.

Qualitative Test Analysis Results

In this section, the analyses of the art rubrics and reflection forms are presented.

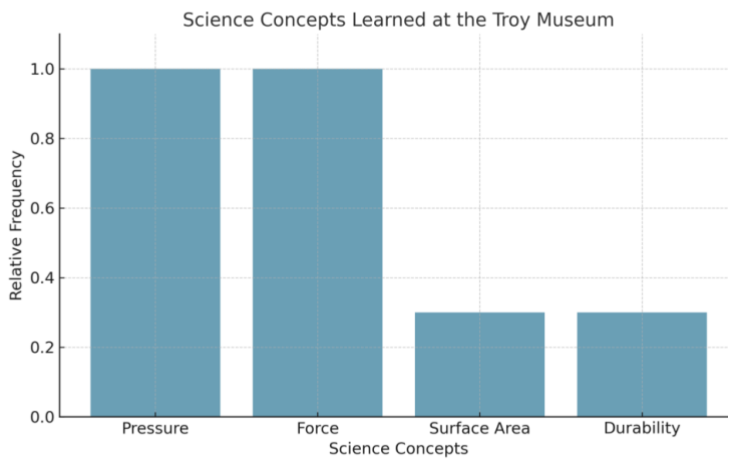
Figure 5.
Comparison of Learning Expectations and Outcomes at the TROY Museum.



As shown in Figure 5, students' expectations prior to the visit to the Troy Museum mainly focused on historical artifacts (*f = 10*), the Trojan Horse (*f = 8*), and places where sculptures are found (*f = 4*). This pattern reflects a preliminary interest in tangible historical objects and the legendary narratives associated with Troy.

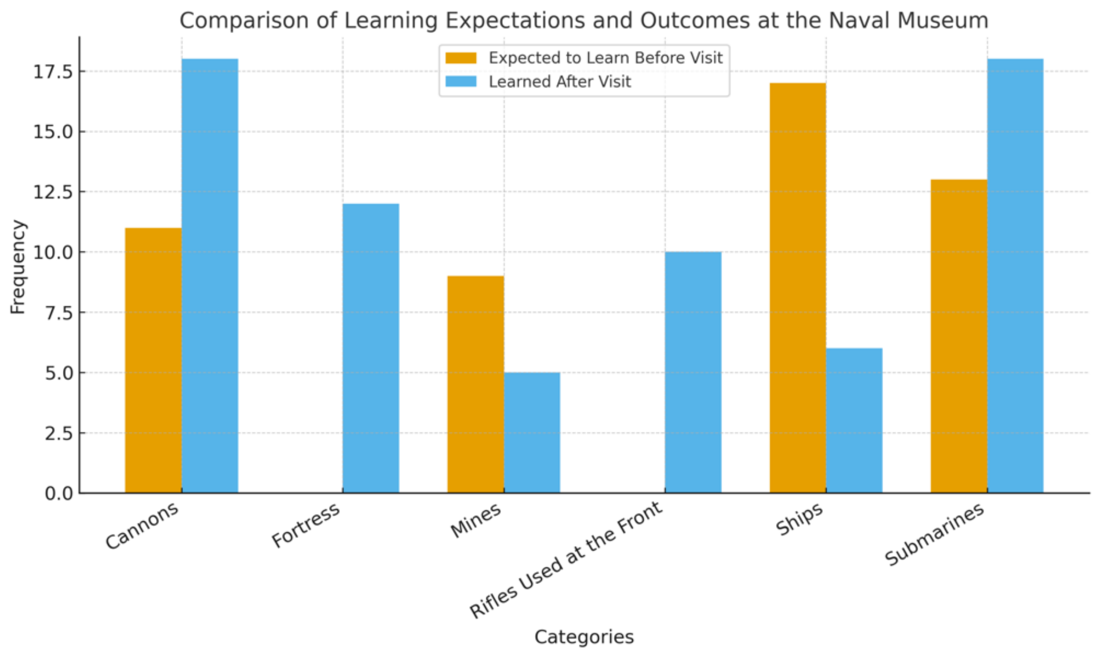
After the museum visit, students' responses exhibited a clear diversification of learned themes. The highest frequencies were recorded for graves and sarcophagi (*f = 18*), sculptures (*f = 16*), and pottery/ceramics (*f = 12*). Additionally, new categories such as the history of historical artifacts and ancient weapons emerged in the post-visit data, indicating an expansion of conceptual understanding beyond initial expectations.

Figure 6.
Science Concepts Learned at the TROY Museum.



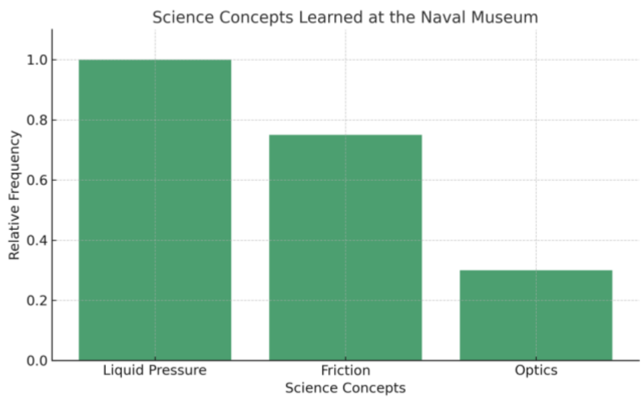
As illustrated in Figure 6, the most frequently identified science concepts learned during the Troy Museum visit were pressure and force, both with a relative frequency of *1.00*. These findings indicate that students strongly associate the museum experience with physics-based principles underlying structural balance and stability. Concepts such as surface area and durability were mentioned less frequently (*0.30* each), suggesting that while some students connected these ideas to observed artifacts—such as statues, tools, and ancient constructions—these notions were less salient compared to the dominant physical concepts of pressure and force.

Figure 7.
Comparison of Learning Expectations and Outcomes at the Naval Museum.



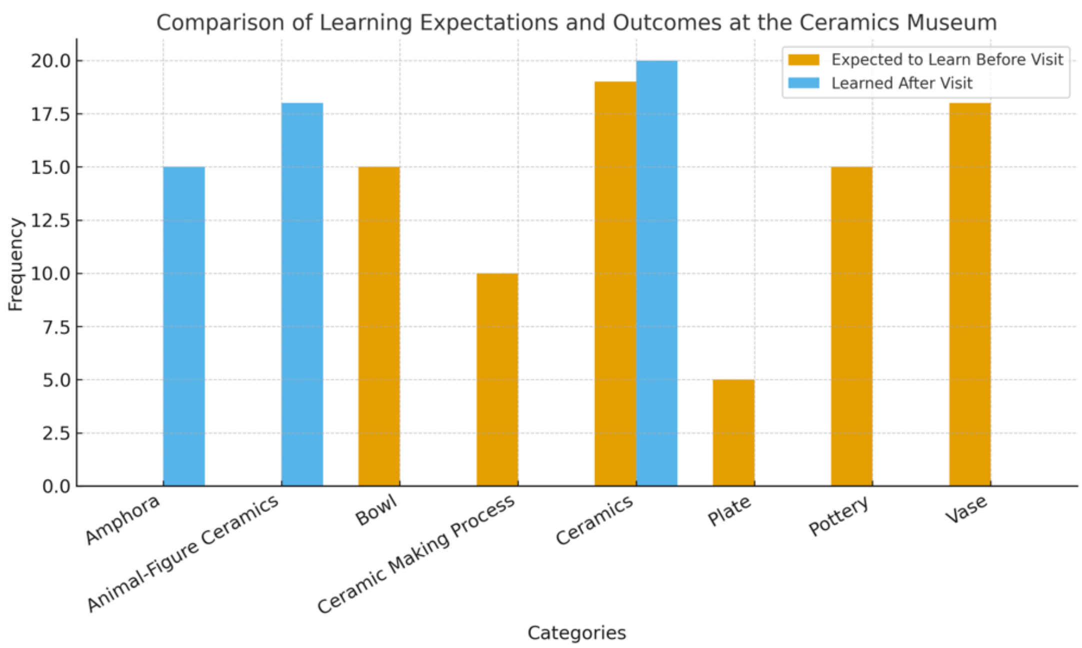
As shown in Figure 7, the comparison between students' expectations before the museum visit and their learning outcomes afterward demonstrates both reinforcement and expansion of conceptual understanding. Before the visit, the majority of students expected to learn about ships (*f = 19*), submarines (*f = 13*), and cannons (*f = 11*).However, after the visit, the frequency of responses shifted notably toward submarines (*f = 18*), cannons (*f = 18*), and new categories such as rifles used at the front (*f = 10*) and fortress structures (*f = 12*).This indicates that while students' initial expectations were largely centered on recognizable maritime objects, their post-visit learning reflected a deeper awareness of military technology and historical context. The emergence of new categories (e.g., *Rifles Used at the Front*) suggests that the museum visit effectively broadened students' perspectives, encouraging them to connect scientific and historical concepts through direct observation and inquiry.

Figure 8.
Science concepts Learned at the Naval Museum.



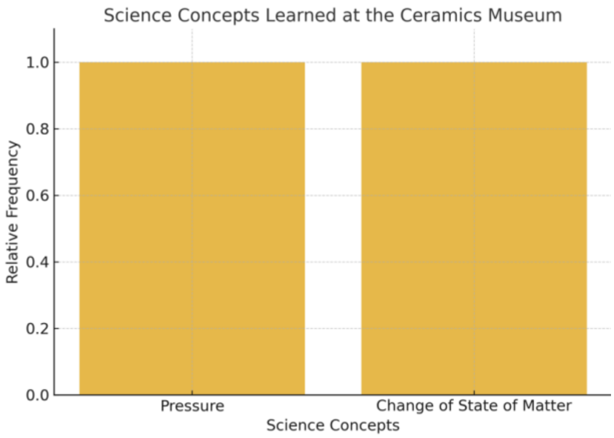
As presented in Figure 8, the most frequently identified science concept learned during the Naval Museum visit was liquid pressure (*relative frequency* = *1.00*). This outcome aligns with the museum's thematic focus on maritime objects, such as submarines, ships, and torpedoes, which provide tangible contexts for understanding the principles of fluid mechanics. The second most mentioned concept was friction (*0.75*), reflecting students' recognition of mechanical interactions and motion dynamics observed in exhibits related to naval machinery and weaponry. Meanwhile, optics (*0.30*) was less frequently noted, suggesting that visual or light-based learning elements—though present—were less prominent within the museum context.

Figure 9.
Comparison of Learning Outcomes at the Ceramics Museum.



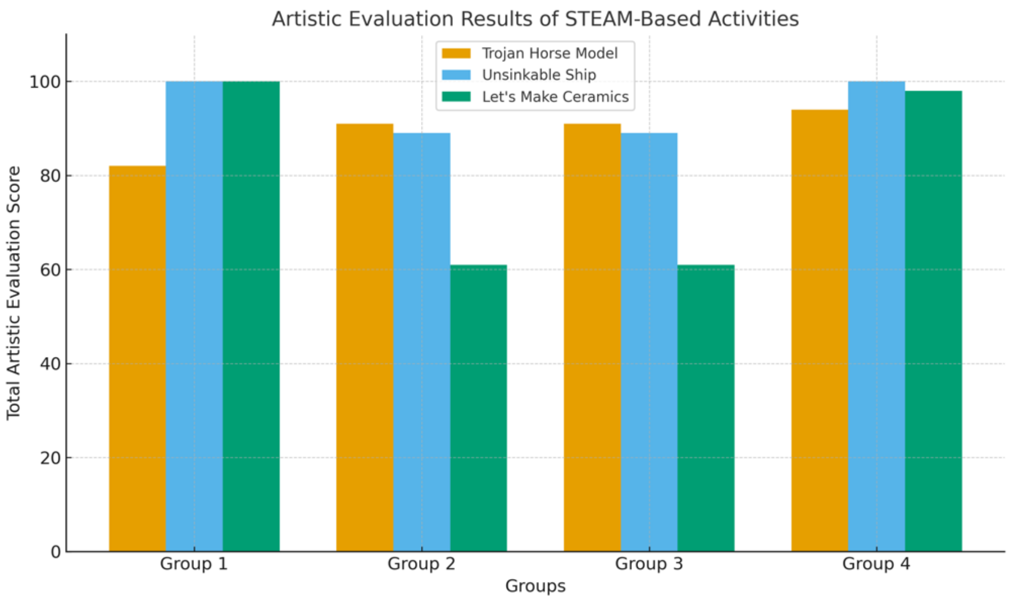
As illustrated in Figure 9, students' expectations prior to the museum visit were primarily centered on ceramics (*f* = *19*), vases (*f* = *18*), and pottery (*f* = *15*). This indicates that learners anticipated observing a variety of ceramic artifacts and understanding traditional production techniques. After the visit, the frequency of responses showed a notable shift: ceramics remained the dominant category (*f = 20*), while new themes such as animal-figure ceramics (*f = 18*) and amphorae (*f = 15*) emerged.

Figure 10.
Science concepts Learned at the Ceramic Museums.



As presented in Figure 10, the science concepts most frequently identified during the Ceramics Museum visit were pressure and change of state of matter, both with a relative frequency of *1.00*. This finding suggests that students effectively connected the museum exhibits particularly the pottery-making processes and kiln demonstrations with physics and chemistry principles related to heat, pressure, and material transformation. The strong association between these two concepts indicates that the museum environment successfully facilitated students' understanding of how scientific phenomena manifest in real-life artistic practices**.** Specifically, the process of ceramic formation and firing enabled learners to observe phase change (solid–liquid–solid transitions) and the effects of pressure and temperature in shaping materials.

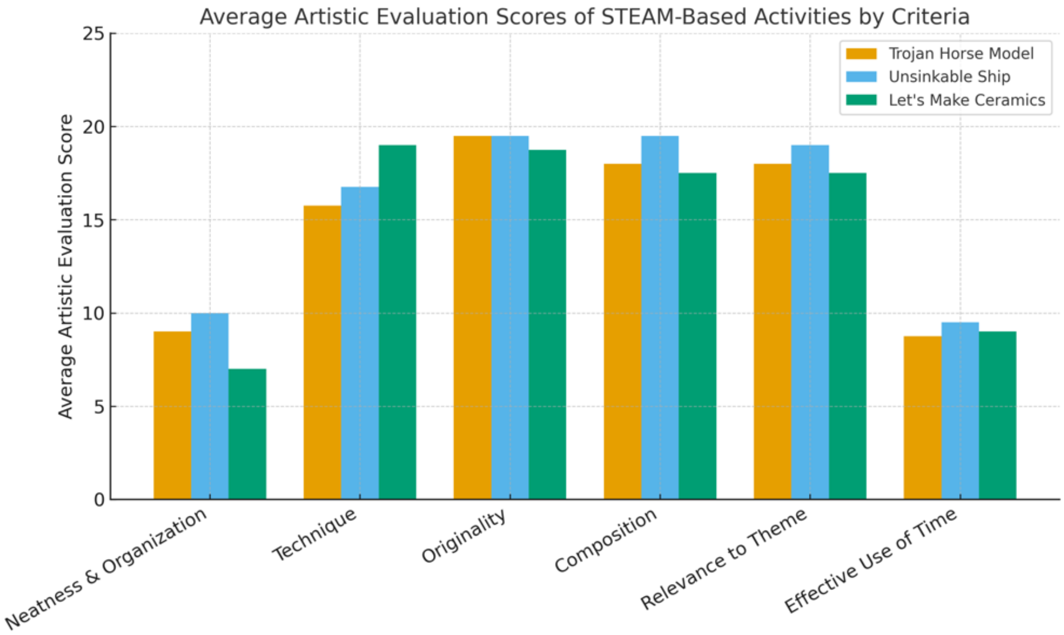
Figure 11.
Artistic Evaluation Results of STEAM-Based Activities.



As illustrated in Figure 11, the total artistic evaluation scores of the three STEAM-based activities show consistent yet differentiated levels of performance among the groups. The "Trojan Horse Model" activity yielded relatively high scores across all groups, with

Group 4 achieving the highest result (*94 points*), indicating strong artistic and technical engagement. Similarly, in the "Unsinkable Ship" activity, both Group 1 and Group 4 attained the maximum score (*100 points*), suggesting effective collaboration and mastery of aesthetic and compositional criteria. In contrast, the "Let's Make Ceramics" activity displayed the widest variation in total scores (from *61 to 100 points*), reflecting greater diversity in creativity, technical execution, and time management among participants.

Figure 12.
Average Artistic Evaluation Scores of STEAM- Based Activities by Criteria.



As illustrated in Figure 12, the comparative analysis of average artistic evaluation scores across the three STEAM-based activities Trojan Horse Model, Unsinkable Ship, and Let's Make Ceramics reveals both consistencies and variations among different artistic criteria. Overall, the Unsinkable Ship activity demonstrated the highest mean scores across most categories, particularly in technique (16.75), composition (19.5), and relevance to theme (19). These results suggest that students were able to effectively combine engineering precision with artistic creativity in a balanced manner, reflecting the integrative aims of STEAM education.

The Trojan Horse Model activity also showed strong outcomes, particularly in originality (19.5) and composition (18), indicating that students could creatively interpret historical and cultural artifacts through hands-on construction. However, relatively lower averages in neatness and organization (9) and effective use of time (8.75) suggest that students may have prioritized creativity over craftsmanship or time management during the process.

In contrast, the Let's Make Ceramics activity presented wider score variability, with high ratings in technique (19) and originality (18.75) but lower averages in neatness (7) and time management (9). This pattern implies that while students displayed strong technical and creative potential, challenges arose in maintaining consistency and organization when engaging with unfamiliar materials and artistic media.

DISCUSSION

The findings of this study demonstrate that museum-based STEAM activities significantly improved students' understanding of scientific concepts, cultural heritage awareness, and artistic skills. The quantitative results revealed meaningful increases in both conceptual knowledge and cultural heritage awareness, while the qualitative findings showed expanded thematic understanding, deeper contextualization, and strengthened interdisciplinary connections. These outcomes align with previous research emphasizing the effectiveness of integrating STEAM practices into authentic learning environments (Gültekin & Demir, 2022; Henriksen, 2013; Perignat & Katz-Buonincontro, 2019).

First, the significant difference between pre- and post-test concept scores indicates that STEAM-based museum activities support meaningful learning by situating abstract science concepts within real-world contexts. Prior studies similarly emphasize that integrating science learning with hands-on, experiential tasks improves conceptual retention and promotes higher-order thinking (Graham & Brouillette, 2016; Yakman & Lee, 2012). The museum visits in this study supported by Kolb's Experiential Learning Theory enabled students to observe, reflect, conceptualize, and apply scientific ideas, thereby enhancing conceptual depth. Museums offer opportunities for students to connect scientific content with real-world cultural artifacts, resulting in enhanced cognitive engagement and more durable learning (Kim & Park, 2020; Tran et al., 2021).

Second, the increase in students' cultural heritage awareness is consistent with national and international scholarship that positions museums as powerful contexts for cultural learning (Korkmaz et al., 2019; Pereira et al., 2024). Direct interaction with artifacts and culturally meaningful environments supports identity formation, historical understanding, and emotional engagement. Previous research argues that cultural heritage learning improves when science, art, and history are blended through interdisciplinary pedagogy (Anderson, 2021; Helvacı & Yılmaz, 2020; Xu ,2023). The current findings provide empirical support for this integrative approach.

Third, qualitative data demonstrated that students identified numerous science concepts during the museum visits—particularly pressure, force, fluid mechanics, heat, and phase change highlighting the potential of museums to function as informal laboratories. This aligns with Liao (2016) and Guyotte et al. (2015), who report that STEAM environments stimulate creativity and interdisciplinary reasoning while supporting science learning through artistic practices. Students' artistic products in the present study also revealed gains in creativity, technique, composition, and theme relevance, consistent with research demonstrating that STEAM projects enhance artistic thinking, craftsmanship, and problem-solving (Madenci & Yılmaz, 2019; Zhang & Jia, 2024).

A unique strength of this study lies in its emphasis on assessment rigor. Belbase et al. (2022) highlighted a major gap in STEAM research: the lack of systematic and standardized evaluation tools. By employing a validated art rubric and establishing inter-rater reliability, this study contributes to addressing that gap. The ability to evaluate artistic skills not only strengthens data quality but also expands methodological possibilities for future STEAM studies, particularly those situated in cultural learning contexts.

Finally, the use of Kolb's learning cycle proved to be an effective pedagogical structure. Consistent with Kim and Park (2020) and Tran, Huang, and Hung (2021), students progressed naturally from concrete experience to active experimentation, reinforcing both scientific and artistic learning. The iterative design tasks such as the Trojan Horse model and the Unsinkable Ship enabled students to apply scientific principles while demonstrating creative expression, supporting literature that emphasizes the synergy between experiential learning and STEAM innovation (Gülhan & Şahin, 2018; Özkan &

Topsakal, 2021). Overall, the study contributes to growing evidence that STEAM learning conducted in museums promotes deep conceptual learning, cultural awareness, and artistic skill development through integrated, experiential, and hands-on approaches.

This study concludes that museum-based STEAM activities are highly effective in enhancing middle school students' science learning, cultural heritage awareness, and artistic skill development. The integrated design combining authentic museum experiences with STEAM-oriented design tasks successfully strengthened conceptual understanding of physics and chemistry topics, increased students' recognition and appreciation of cultural heritage, and facilitated notable improvements in artistic creativity and technical competency.

The results highlight that museums serve as powerful informal learning environments where students engage with real-world phenomena, observe scientific principles in tangible forms, and connect science with culture, art, and engineering. The structured integration of Kolb's experiential learning cycle further supported deep learning by guiding students through phases of observation, reflection, conceptualization, and experimentation.

The study therefore demonstrates that STEAM practices, when embedded within culturally meaningful contexts such as museums, can simultaneously achieve academic, cultural, and artistic learning goals offering a holistic model for future science education initiatives.

Implications

The findings of this study suggest several implications for educators, curriculum designers, and policymakers. First, integrating STEAM-oriented activities into museum-based learning environments can enhance students' conceptual understanding, creativity, and cultural awareness, particularly when supported by structured pre- and post-visit tasks. Strengthening collaboration between schools and museums is essential to align exhibitions with curriculum outcomes and enable students to experience scientific concepts in authentic contexts. In this regard, the systematic use of experiential learning frameworks, such as Kolb's Experiential Learning Theory, may support the design of pedagogically coherent museum-based learning processes. Additionally, incorporating artistic production into science learning can reinforce conceptual understanding while fostering creativity and interdisciplinary thinking. From a professional development perspective, teachers should be supported through training programs focused on integrated STEAM pedagogy and museum education. The findings also highlight the importance of expanding equitable access to informal learning environments, particularly for disadvantaged learners. Finally, future initiatives should prioritize long-term, interdisciplinary STEAM projects that integrate science, engineering, art, and cultural dimensions to promote sustained and transferable learning outcomes.

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