Revista Românească pentru Educație Multidimensională
ISSN: 2066-7329 | e-ISSN: 2067-9270
Abstracting & Indexing | Clarivate Analytics - Web of Science (WoS); EBSCO; Google Scholar; ICI Journals Master List - Index Copernicus; Ideas RePeC; Econpapers; Socionet; CEEOL; Philpapers; KVK; WorldCat; CrossRef; J-GATE

2025, Volume 17, Issue 4, pages: 398-430 | https://doi.org/10.18662/rrem/17.4/1062
Submitted: September 2, 2025| *Accepted for publication:* October 15, 2025

Science Education in Museums with Preservice Science Teachers: "Discovering the Power of Science in Museums"

Hikmet SÜRMELİ [1*]
Ganime AYDIN [2]
Aysun ÖZTUNA KAPLAN [3]
Mehpare SAKA MELEN [4]

[1] Mathematics and Science Education Department, Mersin University, Mersin, Turkey; hsurmeli@mersin.edu.tr; ORCID: https://orcid.org/0000-0001-7052-2574;
[2] Chemistry and Chemical Processing Technologies, Çanakkale Onsekiz Mart University, Çanakkale, Turkey; ganimeaydin@comu.edu.tr; ORCID: https://orcid.org/0000-0001-6112-5243;
[3] Mathematics and Science Education Department, Sakarya University, Sakarya, Turkey; aoztuna@sakarya.edu.tr; ORCID: https://orcid.org/0000-0001-8133-312X;
[4] Mathematics and Science Education Department, Trakya University, Edirne, Turkey; msaka@trakya.edu.tr; ORCID: https://orcid.org/0000-0001-9730-8607;
[*] *corresponding author: hsurmeli@mersin.edu.tr*

Abstract: *Museums, often described as cultural repositories, provide unique environments that help individuals connect the past, present, and future to understand their culture better. Beyond their cultural significance, museums serve as valuable educational spaces where teachers can enhance their scientific knowledge, develop pedagogical skills, and design meaningful learning experiences. Based on the idea that every object in a museum can serve as a teaching tool, the project "Exploring the Power of Science in Museums", supported by the TÜBİTAK 2237-A Scientific Education Activities Support Program, was implemented to enable pre-service science teachers to establish meaningful connections between artifacts displayed in archaeology and maritime museums and science concepts. A qualitative research design was employed in this study. Data were collected through worksheets, lesson plans, and observation forms. The findings revealed that all pre-service teachers' perspectives on museums changed positively; most could associate museum objects with science subjects and recognized the potential of museums as dynamic environments for science education.*

Keywords: *museums; science education; pre-service science teachers.*

How to cite: Sürmeli, H., Aydın, G., Öztuna Kaplan, A., & Saka Melen, M. (2025). Science education in museums with preservice science teachers: "Discovering the power of science in museums". *Revista Românească pentru Educație Multidimensională, 17*(4), 398-430. https://doi.org/10.18662/rrem/17.4/1062

©2025 Published by In Manifest Network in partnership with LUMEN Publishing. This is an open access article under the CC BY-NC-ND license https://creativecommons.org/licenses/by-nc-nd/4.0/

Introduction

The word museum is derived from the Greek word "museion", meaning the thinking place or temple of the muses. In the late 18th century, the museum began to tell a building used to store and exhibit objects related to cultural heritage, rather than the collection itself. Today, the term museum has been dramatically expanded to include art galleries, science and discovery centres (Onur, 2012). The definition of a museum has evolved; however, according to the current version adopted by the International Council of Museums (ICOM, 2022), a museum is a permanent, non-profit institution that serves society by conducting research, collecting, preserving, interpreting, and exhibiting tangible and intangible heritage. Publicly accessible and inclusive museums promote diversity and sustainability, work and communicate ethically, professionally, and with community involvement, providing various educational experiences, enjoyment, reflection, and knowledge sharing." Museums, also referred to as cultural repositories, are seen as a unique environment where individuals can acquire new information about the environment they live in and help individuals understand their culture by associating the past, present, and future (İlhan et al., 2014; Lasky, 2009).

Education in museums

Education and museums have been interconnected since museums were first established. Museum education evolved, shaped by changes in social life, education, and museology. The Enlightenment in France and the 1789 French Revolution opened museums to the public. During the 19th-century Industrial Revolution, museums adapted to urban, science-driven life by exhibiting industrial and technological developments. They also began hosting conferences, courses, events, and educational programs for school groups to engage the public. The role of museums in education evolved throughout the 20th century, especially during and after the World Wars. European museums initially used exhibitions to convey key ideas and educate children during the First World War. In Turkey, museology gained importance with the Republic's establishment, leading to the creation of local museums, which became integral to science-related education. The museums established later were also accepted as a source of learning (Bennett, 1995, cited in Ateş & Lane, 2020). After the proclamation of the Republic, education in museums was emphasized in science-related curricula (Altınok & Tunç, 2013).

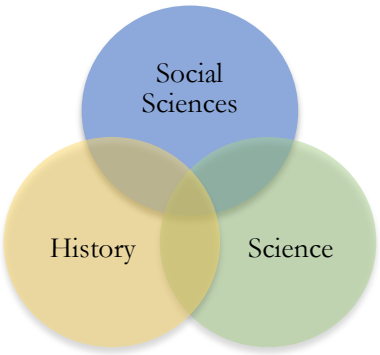
After the Second World War, the educational role of museums grew (Tezcan Akmehmet, 2014), with John Dewey emphasizing their potential for experiential learning. Museums have since been recognized for supporting constructivist learning and fostering independent learning (Hein, 2004). Research has stated that museums support constructivist learning and provide learning environments where individuals can learn independently (Griffin, 2004; Kratz & Merritt, 2011; Mercin, 2017). By the 1970s, museum education expanded to various age groups, significantly impacting educational practices by the 1980s. However, in Turkey, communication gaps between museum staff and teachers highlight the need to increase teacher awareness of museum activities to strengthen school-museum collaborations (Tezcan-Akmehmet, 2014). A study in Turkey revealed communication gaps between museum staff and teachers, emphasizing the need to raise teachers' awareness of museum activities and the importance of museum education (Ateş & Lane, 2020).

Types of museums that can be used as interactive learning environments are archaeological museums, art museums, history or anthropology museums, living museums, historical house museums, children's museums, community-based museums, military museums, natural history museums, science museums, and specialized museums (Karadeniz & Sivrikaya, 2020). Science museums, one of these museum types, are out-of-school learning environments where primary and secondary school students can acquire scientific knowledge and scientific skills. However, museums where scientific knowledge can be obtained are not limited to these places. Researchers also emphasize that students can develop this knowledge and these skills in museums (Georgopoulou et al., 2020).

Science education in museums

Archaeology is traditionally classified within the social sciences; it is inherently interdisciplinary. As a branch of anthropology, archaeology bridges science, social studies, and history (Figure 1), fostering scientific inquiry and reasoning (Moe, 2011). It employs methods and knowledge from biology, geology, soil science, and chemistry to analyze data and make inferences about past environments and human lifestyles (Moe, 2011). Archaeology contributes to understanding human history and making meaningful connections to scientific thinking and methodology through this integrative approach.

Figure 1 Archaeology as he Link Between Science, History and Social Sciences (Moe, 2011)



Building upon this integrated framework, archaeological museums are essential resources for history, natural sciences, and technology education. They are dynamic learning environments where archaeology's cultural and scientific aspects merge and provide worthwhile educational possibilities (Smardz, 1989; Copley, 2010; Geiger, 2004). Due to these features, various studies have been conducted on this subject, in the belief that they will contribute to learning science concepts and the acquisition of scientific skills (Crawins, 2014; Georgopoulou & Koliopoulos, 2017; Jeppson & Brauer, 2007; Letts & Moe, 2009; Moe, 2011). Research indicates that primary and secondary school students are the main visitors of archaeological museums (Georgopoulou et al. 2020; Jeppson & Brauer, 2007). Museum education should be tailored to this age group, focusing on the knowledge, skills, and values they need to acquire. A study connecting museum objects to contemporary scientific knowledge helped primary students gain new perspectives on science and technology (Georgopoulou & Koliopoulos, 2017). Another survey of fifth graders' understanding of scientific inquiry through archaeology found that most students grasped scientific inquiry concepts and the link between science, history, and archaeology (Letts & Moe, 2009, cited in Moe, 2011). Research comparing object-oriented and science skill-oriented activities showed that younger students preferred object-based learning, though museums are also crucial for science-based activities (Crawins, 2014). The Archaeological Science Classroom Activities Guide also offers adaptable activities for primary and secondary students, integrating archaeology with laboratory methods (Nikita et al., 2022).

These museums are also ideal for reinforcing STEM principles (Cooper, 2003; Geiger, 2004; Owen & Steele, 2005) as their artifacts provide visual and tactile links to natural science concepts (Georgopoulou & Koliopoulos, 2017). It is suggested to shift from teaching archaeology to

teaching with archaeology to enhance learning across social sciences, mathematics, and science (Higgins & Holm, 1985). Through experimental archaeology, ancient Roman technologies can be linked to modern science and technology (Cooper, 2003; Geiger, 2004; Owen & Steele, 2005; Roy, 2019). In such studies, it is essential to establish strong connections between archaeology, science, and technology to enhance understanding and interdisciplinary learning (Cooper, 2003; Davis, 2000; Geiger, 2004; Jeppson & Brauer, 2007). A project involving teachers from various countries found that integrating archaeology into STEM lessons enhanced students' curiosity, problem-solving, critical thinking, and model-building skills. Teachers noted the applicability of these practices in classrooms but expressed a need for further training (Díaz, 2016).

In addition to archaeological museums, archaeological parks, which are defined as public archaeological sites containing archaeological findings (Eres, 2018), are also valuable in terms of education. Various practices and activities are held in these areas (Karul et al., 2010; Karul, 2015). In this regard, within the scope of the current study, an archeopark was visited and examined as an archaeological excavation site.

One of the types of museums that can be organized for learning purposes is maritime museums, which can be considered within the scope of military museums. Although there is no clear definition of these museums, they are related to shipbuilding, docks, dock areas, traditional ships of all types, inland waterways, navigation and navigation aids, sailors, and maritime art. It also helps to understand how maritime trade and naval warfare have shaped and continue influencing our world (Davies, 2012). There are limited scientific studies in the literature evaluating maritime museums as educational environments. These museums, which are potential educational spaces, allow students to explore maritime-related subjects, learn approaches at the forefront of visual and practical applications, and are associated with science and social studies curricula.

The researchers emphasized the importance of maritime museums and the need to introduce maritime education from a young age, highlighting that aspiring teachers can raise awareness of marine and coastal environmental conservation among future generations. In their study, this kind of instruction helps students understand basic scientific ideas and apply them to real-world situations, including marine sustainability. Findings indicated that undergraduate students in chemistry education enhanced their understanding of key concepts in science Education -including the nature of science, the role of science teachers, elements of science learning, and learning theories- within the framework of sustainable maritime education (Fitriani et al., 2024).

Archaeology museums and maritime museums, which combine scientific methods with the study of historical artifacts, significantly enhance their educational potential across both the natural and social sciences. Their capacity to shed light on many facets of the past and present emphasizes their educational worth even more. In light of those mentioned above, by associating them with the Science Curriculum, students can gain the knowledge, skills, and values the course targets. Researchers also highlight the role of museums as informal learning environments in science education, noting both benefits and challenges for teachers integrating these experiences into classrooms (Anderson et al., 2003). Teacher training in informal learning environments is crucial, as trained teachers utilize these spaces more effectively (Türkmen, 2018). Preservice teachers' engagement with natural history museums during their studies enhances their understanding of informal learning and helps them link science courses to museum experiences (Sönmez & Öztürk, 2022). While museums positively impact science teaching and learning, there are limitations in preservice teachers' experiences (Lau & Sikorski, 2018). In this regard, sharing the experiences in the applications, evaluating the activities carried out, and determining the extent of contribution that can be made to the professional development of science teaching are essential. In museums, science teachers can benefit from innovative teaching approaches, turn scientific studies into teaching materials, and help make science learning more accessible and engaging for students. From this perspective, museums are seen as suitable areas for teacher education.

In Turkey, an informal environment is included as a 2-credit course in preservice science teachers' programs. The course includes planning, implementation, evaluation studies, instructional strategies, resources, and approaches appropriate for informal learning settings. Museums have been suggested as informal learning environments. (Council of Higher Education (YÖK), 2018). As a sample application for this course, archaeology museums, maritime museums, and archaeological sites were used as interactive learning environments in this study. Based on the idea that museums are used as science education environments and that every object in the museum is a teaching tool, in the scope of this study, activities were carried out to enable preservice science teachers to establish a context between the artifacts exhibited in the Archaeology and Maritime Museums. The study aims to set an example that museums, though not directly related to science, can also be associated with science education. The main problem of working in this direction was: "How do the activities held in museums contribute to preservice science teachers' ability to establish a context

between museums?" The study aims to help preservice science teachers understand that museums can be used as science teaching environments, to help them develop competencies in preparing lesson plans in which they use museums as educational environments, and to experience activities integrated with the objects they examine in the museums and the scientific disciplines.

Methodology

This study was designed within a qualitative research paradigm, adopting an explanatory case study approach to explore preservice teachers' perceptions of museums and their connections to science education. A qualitative orientation was preferred because the study aimed to understand participants' subjective experiences and interpretations rather than generalize findings. Yin (2018) described that the case study methodology enables researchers to explore complex phenomena within real-life contexts and uncover the causal mechanisms underlying participants' experiences. The "Exploring the Power of Science in Museums" project, supported by the TÜBİTAK 2237-A Scientific Education Activities Support Program, served as the research setting within this methodological framework. The perceptions of preservice teachers about museums in out-of-school learning contexts, the difficulties they encountered in relating museums to science education, and the gaps identified in the literature guided the choice of an explanatory case study to reveal the cause-and-effect relationships in this domain.

Data were collected to understand preservice teachers' perceptions and experiences of museums and their reflections on linking museums to science education. These data provided insights into their awareness and competencies regarding the educational role of museums in science teaching. The prospective teachers' thoughts on this issue were absorbed during and after the training process within the project's scope. Consequently, the research aimed to explain how participation in the project contributed to changes in their thinking and learning processes.

Study group

In selecting preservice teachers participating in the project, the following criteria have been considered: having a balanced number of male and female participants and being educated in the 3rd and 4th grades of different universities' Science teacher education programs. Through these criteria, 20 preservice science teachers from 18 universities in Turkey were selected to participate in the project. Participants willingly took part in this

project. Two of the participants left the project due to the February 6 earthquake. While 4 of the preservice teachers participating in the project had not attended courses on museum education before, 14 of them had participated in courses on museum education. The participants' applications were selected through the project's web page, and the selection of preservice teachers was completed in line with the specified criteria.

Data collection and analysis

Preservice teachers were asked to prepare worksheets, observation forms, and lesson plans in which they would make museum-science associations within the framework of the science course curriculum. Worksheets (Predict-Observe-Explain) and open-ended question forms developed by the researchers, lesson plans prepared by preservice teachers, and observation records of the researchers were utilized as data collection tools in this study. A form consisting of open-ended questions about preservice teachers' perceptions and experiences about museums and their thoughts on associating them with science education was applied as a preliminary application. The questions aimed to explore how preservice teachers conceptualize museums, how they perceive their educational potential, and how they relate museums to science teaching and learning. Some of the questions in the form are presented below as examples:

What do you understand by the word museum?

How do you think museums can be used as an out-of-school learning environment?

What do you think about using museums as science teaching environments?

What kind of museums can be used in science education?

At the end of the project, a form containing questions was applied to understand whether there was a change in the preservice teachers' perceptions of museums and their association with science education. The questions aimed to evaluate how the project influenced their understanding of the relationship between museums and science classes, as well as their views on the use and planning of museums as learning environments for science education. Some of the questions in the form are presented below as examples:

Did the project you participated in;

Affect your thoughts about the relationship between museums and science classes?

Was it effective in the use of museums as science education environments?

Was it effective in the planning of museums as science education environments?

Worksheets (Predict-Observe-Explain) are organized as follows:

Table 1. Predict-Observe-Explain Worksheets

Predict: Do you think there is a relationship between the archaeological museum and science class? Please explain. What science subjects do you think the works in the archaeological museum

Observation: Fill in the table below while examining the works during your museum visit.
Write down which scientific subjects and concepts the works you examine are related to.

Science related topics and	Objects in the museum	Give an example concept

Explain: Explain how the archaeological museum and science class can be related.

The Prediction Observation Explain worksheet was developed by the researchers in the Table 1 prepared to be applied before and after museum visits. Before the museum visit, it assisted the participants in associating science subjects with the objects on exhibition. Observation and explanation phases of the worksheet were used following the museum visit and activities about the objects displayed in the related museum.

Content analysis technique was used to analyse open-ended questionnaires to determine the opinions of preservice teachers regarding the project evaluation before and at the end of the project training. The descriptive analysis technique was used in the analysis of the worksheets applied before the museum visits and after the activities held regarding the objects exhibited in the visited museum, and the ability of the preservice teachers to establish a relationship between museum and science subjects was determined. In addition, the observation records the researchers collected during the project training process were evaluated with the relevant data to contribute to the data analysis process. Two experts in the field carried out the data analysis process, and the findings with disagreements were reviewed and evaluated.

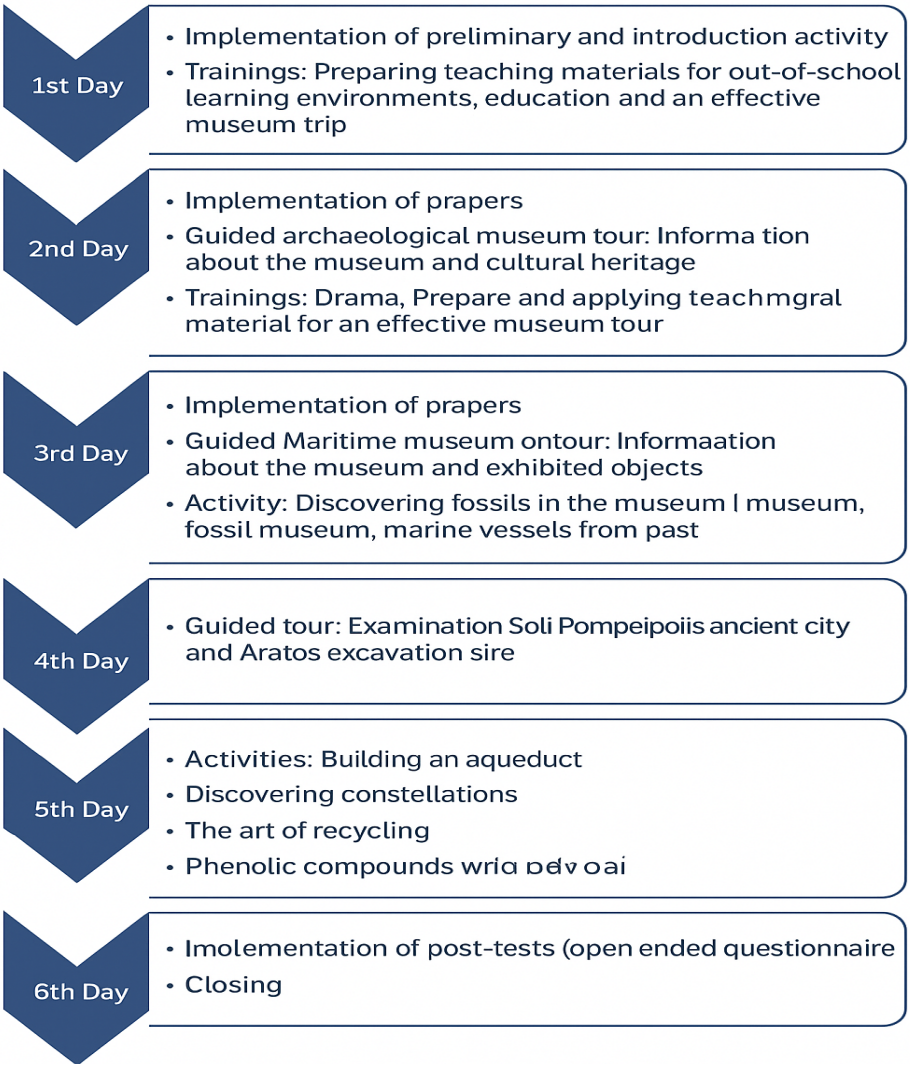
Application process

The project was carried out for six whole days. Before the beginning of the project, experts who worked as researchers and instructors examined the archeological and maritime museums to be visited during the project, and they identified objects that could be associated with science subjects

included in the science curriculum. They planned the activities that would be implemented. Within the project's scope, the same experts provided training on out-of-school learning environments, museum education, preparing teaching materials for an effective museum education, and drama to the preservice science teachers. Detailed tours were organized in the Mersin Archeology Museum, the Maritime Museum, Soli Pompeiopolis, and the Aratos excavation area, and awareness was raised among preservice teachers on how to relate science subjects.

Before each museum visit, participants completed a prediction worksheet. In the archaeology museum, they explored artifacts from the Neolithic, Chalcolithic, and Bronze Ages, including agricultural tools, Roman accessories, olive oil production items, coins, amphoras, and a display of Aratos. Preservice teachers at the Mersin Maritime Museum examined ship models from various periods, weapons, navigational instruments, and a fossil exhibition. They also visited the ancient city of Soli, inspecting its colonnaded road, harbor, Roman bath, aqueduct, and Aratos' mausoleum. After visiting each museum and archeopark, preservice teachers participated in activities (shown in Figure 2) that integrated science, history, and art in the classroom, in which associations were made with objects exhibited in the museums and archeopark. The activities carried out and the implementation plan are presented in Figure 2. After each museum visit, participants were asked to fill out the Observe-Explain worksheet.

Figure 2. Implementation plan of the project



Findings

Pre-project Museum experiences of preservice science teachers'

Table 2. Preservice science teachers' purposes for visiting museums

Theme	Code	f
Travel purposes	To travel	8
	To satisfy your curiosity	4
	To see the surroundings and environment	1
	Being curious about the lifestyle of people who lived in the past	1
	To see the artifacts	1
	Total	**15**
Getting information	Learning about ancient cultures and lifestyles	2
	Exploring structures of history, art and literature	1
	Learning about materials used in the past	1
	Increasing general culture	1
	Seeing works related to history class	1
	Total	**6**
Establishing connection with the course	To visit	1
	To see the artifacts	1
	To realize a school project	1
	Total	**3**

Preservice Science Teachers visit museum mostly for sightseeing purposes. While some stated that they visited them for informational purposes, a small number of preservice teachers stated that they visited the museums as part of the course. The statements of some of the preservice teachers' regarding the subject are as follows:

K6: Because I am interested in traveling, having a good time and cultural issues about the past.

K3: I visited (i.e. the museum) because I was curious about the lifestyles of the people who lived in that period

Table 3. Positive and negative opinions of preservice science teachers' regarding their museum visits

Positive	**f**
Making inferences about past	8
Establishing a connection with the past	3
Making investigations	2
Observing remarkable environments	2
Uncodable	2
Negative	**f**
No guide in museums	4
Lack of information about the objects	3
Neglect/lack of care in the museums	2
Insufficient time for the school trip	2
Noisy environment	1
Inability to relate to the course	1
No negative comments	6

Preservice science teachers have positive and negative opinions regarding museum visits. While most made inferences about the past and expressed their opinions about learning, some of them stated that the visit to the museum provided positive gains in terms of connecting with the past and trying to understand it, making investigations and seeing remarkable environments. Students expressed their opinions as follows:

E2: I saw historical buildings and objects and the way people lived in the past.

K8: The drawings on the stones and what they meant, the efforts of people to worship, the simulations and voiceovers were very good.

The teachers also expressed negative opinions about museums and the visiting process. They made the following statements:

E6: During a trip organized by my school, we were in a hurry because time was limited, and I could not observe carefully.

K8: Lack of guides. Some artifacts or places lacked descriptive information.

While 4 of the preservice teachers that participated in this study had not taken a course on museum education before, 14 of them had attended a course on museum education. The statement of one of the preservice teachers' who did not take the course is as follows:

E3: …, we did not receive any training on how to provide education outside of school and how museums can be learning environments.

Regarding the adequacy of the education received in this project, a small number of preservice teachers (2) were of the opinion that it was

partially sufficient, while most of them (12) stated that it was insufficient regarding the course situation, course content and course duration. Preservice teachers expressed their opinions as follows:

K4: Doing anything related to museums for the purpose of visiting, seeing, experiencing, etc.

E4: Since learning is provided by seeing in museums, I do not think that sufficient importance is given to this issue

Table 4. Preservice science teachers' perceptions of museums before and after the project

Before project implementation	**f**	**After Project implementation**	**f**
Exhibition space, an area where;	8	Showing a Change in Museum Perception	18
artifacts of a culture are exhibited		Awareness about the use of museums as educational environments that;	11
historical tools and equipment are exhibited			
valuable historical items are exhibited		*learning can take place in museums*	
Historical, Culture and Values Environment	5	*museums can be used for educational purposes*	
		museums can be used for out-of-school learning	
Remarkable environment combining past and present		Awareness of the museum environment not just a place;	5
Environment intended to preserve historical events		*to visit*	
Learning area	5	*to see the objects exhibited*	
Informal learning space		*to get cultured*	
Area of learning to explore		Awareness of the content of museums realizing that;	3
Free educational institution			
History, science learning area		*museums have different features*	
Unresponsive	3	*there is much information and objects*	

It was determined that preservice teachers mostly saw museums as exhibition areas (8) before the project implementations. In addition, they described them as environments where artifacts of historical and cultural value are found (5) and as learning areas (5). After the project implementation, all of them stated that their perspectives on museums changed with the education process. It has been determined that this change is particularly due to the fact that museums are seen as an educational environment (11). In addition, some of them stated that their awareness of museum environments (5) and the scope of museums has increased (3). The

statements of preservice teachers who said that museums can be used as educational environments are as follows:

K11: Reconciling the past and the present and connecting this to science broadened my perspective.

The pre-service teachers who believed that their awareness of the museum environment increased expressed the following opinions:

E1: I realized that museums are not just about old, ancient things.

K10: I used to think that museums improve social life, increase our general knowledge and help us gain an understanding of our history, but now I see them as an environment that we can use for education purposes.

The pre-service teachers who expressed their opinions about the scope of museums stated the following:

K9: Because we previously associated it mostly with history and geography lessons. However, when we examined the objects displayed in museums, I realized that science was everywhere and that increased my interest in museums.

Pre-service science teachers' opinions about science education in museums

Before the project implementation, most of the pre-service teachers expressed positive opinions (14) about teaching science in museums. One of them stated that not every museum would be suitable, and another one stated that science centers would be more suitable.

Table 5. Opinions about science education in museums

Before the Project			
Teaching science in museums			**14**
for the students	**f**	**How should it be carried out?**	**f**
Permanent learning	6	Effective planning	1
Skill development *Observation skill* *Exploration skills*	2	*Establishing a relationship with the subject and achievements* *Accompanied by knowledgeable guides*	4 1
increase curiosity	1	Using in the introduction to the course	1
After the project			
Teaching science in museums			**18**
for the students	**f**	**How should it be carried out?**	**f**
Effective learning	6	*Applications involving interdisciplinary relationships*	2
Concretization	4		
Attract attention	3		
Support discovery	2	*Exploration activities on science topics*	2
Development of thinking skills	1	*Research inquiry-based approach*	7

Some pre-service teachers, who expressed positive opinions about science education in museums before the project implementations, stated that permanent learning can be targeted by carefully-planning science teaching in museums and concretizing the subjects (6) and a small number of them were of the opinion that the subject-objective relationship could be established and skills could be developed under guidance (4). At the end of the project, all (18) of them stated that they thought of providing science education in museums. Below are excerpts of their opinions on this subject:

E1: I use it in my activities as an out-of-school learning environment. In this way, it helps students think more broadly and comprehensively.

K2: Yes. As we were able to associate museums and science more, we realized that we could also use museums as science education environments.

Some preservice teachers shared positive feedback, noting that museum-based science teaching can enhance effective learning (6), concretization (4), and student engagement (2) through interdisciplinary connections. Others highlighted that discovery activities (2) and a research-based approach can support exploration and improve thinking skills (1).

For example, K6 stated; *A more student-centered and collaborative teaching process can be achieved with a well-planned museum visit.*

Pre-service science teachers' associations of museums with science subjects

Table 6. Associations with museums and science subjects before the project

Discipline	Relatable Subjects	f
Biology	Living things	4
	Fossils	3
	Anatomy- Skeleton system	2
	Fermentation	1
	Total	**10**
Physics	Astronomy	4
	Simple machines	1
	Pressure	1
	Total	**6**
Chemistry	Alchemy	1
	Chemical reactions	1
	Rocks	1
	Total	**3**
Interdisciplinary	Physics chemistry biology	2

Before the project, most preservice teachers linked museum studies to biology (10), physics (6), and chemistry (3), focusing on topics like living

things, astronomy, and chemical reactions. Few made interdisciplinary connections. All reported an improved understanding of how museums relate to science courses, noting initial difficulties in making these connections. As seen below, they stated that they had difficulty making connections with science subjects before the project, and that the practices carried out during the project created awareness about making connections.

Sample statements of pre-service teachers regarding the subject are as follows:

"I think about the science topics in museums in more detail. How can I convey more information to my students? I realized that museums are not just about old, ancient things."

"I go to museums and pass by them during the visit and say, "Wow, how beautiful!" I realized that they were not just the items we mentioned, but that I could relate them to many areas of science."

"Before, I was just looking at the exhibits in the museum without examining them carefully. I Thought they weren't connected with the science course, but I realized that examining the exhibits carefully provides a lot of information and that museums and science lessons are related.

"During my previous museum visits, I was superficial and acculturated. As a result of this training, my awareness about the place of museums in science education has increased and I will be more meticulous, inquisitive, and able to find and establish relationships in museums."

Table 7. Associations of archeological museums and science subjects – Predict-Worksheet Results

Disciplines	**Relatable Subjects**	**f**
Chemistry	Matter	4
	Chemical reactions	2
	Minerals	1
	Acid-base	1
Physics	Balance	1
	Simple machines	1
Biology	Living creatures and nature	2
	Fossils	1
Geoscience	Natural disasters	2
	Structure of rocks	1
No prediction		3

Before the archaeology practices, 15 preservice teachers predicted connections between science subjects and artifacts in the archaeology museum in the Predict phase of activity. Most linked the museum to

Chemistry (8), with fewer associations in Biology, Physics, and Earth Science. In Chemistry, they related to matter, chemical reactions, minerals, and acids-bases; in Physics, to balance and simple machines; in Biology, to living things and fossils; and in Earth Science, to natural disasters and rocks.

One preservice teacher, who linked the artifacts in the archaeology museum to biology, stated: *"Living things and life can be linked to shellfish and vertebrates."*

One preservice teacher, who linked them to fossils, simple machines, and chemistry, stated: *"Yes, it is. Because you can see fossils, rocks, simple machines used in the past, and materials used by alchemists in the past."*

Another teacher stated: *"The structures might be related to chemistry, what the structures are made of, minerals, ores...*

Another teacher, who linked them to rocks, stated: *"Yes, I think so. The structure of rocks and the materials used can give us some insight."*

Table 8. Associations of archeological museums and science subjects – Observation and Explanation Worksheet Results

Disciplines	Observation	Explanation	f
Chemistry	Dye stuffs	Elements and compounds	10
	Melting metals	Substance and properties	4
	Worn out objects	Acid rains	3
	Earthenware cooking - ceramics	chemical reactions	2
	Terracotta pots	Reactions	2
	Plaster manufacturing	Mixes	2
	Olive oil production	Mixes	5
	Glass production	Heat-temperature	1
	Total		**29**
Biology	Invertebrates, Fossils	Livings and life	8
	Wine making	Fermentation	4
	Seeds	Nutrition	5
	Total		**17**
Physics	Equal arm scale	Mass and weight	3
	Some tools / spinning wheel	Simple machines	5
	Energy produced by friction	Energy	1
	Expand surface area	Pressure	4
	Olive oil pressing	Force, Friction	4
	Instrument	Sound	1
	Lamps	Optic	1
	Ideas of ancient Greek thinkers	Astronomy	1
	Total		**19**
Geoscience	Rocks		4
Climatology	Climate change		3
Nature of Science	Influence of religion	Social and cultural impact	1
	Cumulative knowledge	Scientific knowledge changes	1
	Experiment-observation	Observation and experimentation	1
Interdisciplinery	STEAM		1

After implementing the archaeology museum practices, as a result of the evaluation of the Observe-Explain activity, preservice teachers primarily

associated the museum with Chemistry, followed by Physics and Biology. In Chemistry, they linked six topics, including elements, matter, and chemical reactions. In Physics, they identified eight topics, such as energy, pressure, and optics. For Biology, they connected three topics: living things, fermentation, and nutrition. Few associations were made with STEAM, Earth Science, and Climatology.

Table 9. Associations of maritime museums and science subjects- Guess worksheet results

Disciplines	**Relatable Subjects**	**f**	**Disciplines**	**Relatable Subjects**	**f**
Chemistry	Elements	1	Physics	Buoyancy force	6
	States of matter	2		Floating-Sinking	5
	Intensity	6		Optics - Lenses - Telescope	3
	Physical and chemical change	3			
	Calcification	1		Sound and Features	2
	Solutions	1		Pressure	9
	Properties of matter	1		Magnetism: Compass	4
	Total	**15**		Light	5
Biology	Classification of Living Things	13		Heat-temperature	2
	Fossils	5		Force	3
	Endangered species	2		Balance	2
	Vertebrate-invertebrate creatures	2		Sound (Sonar devices)	5
	Respiratory	5		Simple machines	5
	Reproductive	4		Ebb and flow	1
	Circulation	1		Waves	8
	Anatomy	2		Underground technology	2
	Environmental pollution	6		Conductivity	1
	Evolution	3		Astronomy	3
	Total	**46**		Total	**66**

Before the implementation of the maritime museum practices in the project, pre-service teachers made predictions stating that science subjects could be connected with the artifacts in the maritime museum in the

Prediction phase of the activity. The majority of the teachers associated the maritime museum with the discipline of physics, followed by biology. The least associations were made with the discipline of chemistry. Associations were made with the discipline of physics in 17 subjects, 11 subjects in biology, and 7 subjects in chemistry.

One prospective teacher, who made connections with the artifacts in the maritime museum, stated that:

"… C*ompass, Magnetism, Ship Models, Old Maps. I think the overall learning outcomes are related to Physics. Ship designs can contribute to science in terms of durability, and compasses can contribute to science in terms of magnetism*."

A teacher candidate who connected with different fields stated that:

"*I've never been to a maritime museum before. I think we can see ships, fossils, marine creature remains, and compasses in a maritime museum. We can ask students questions about how ships float and get them thinking. We can ask them how a ship floats without sinking when we throw a stone into the sea. Afterward, we explain density and the buoyancy of liquids. We discuss waves. We talk about water waves. We explain magnetism through compasses. We can connect fossils, marine creatures, and so on to the biology of living things*."

Another teacher stated the following:

"*Examples of boats may relate to the subject of balance. They may be barometers for measuring pressure. They may be coats of arms and sultan's signatures, and heat may have been used in their construction. They may be fossils in the sea. They may be objects where density is important*."

Table 10. Associations of maritime museums and science subjects – Observe-Explain Worksheet Results

Disciplines	Observation	Explanation	f
Chemistry	Gunpowder, steel, amphoras, mines	Chemical reactions	6
	Chromium to harden steel	Element- compound	5
	Steel, chrome, gunpowder	Structure of matter	3
	Armor, cannons	Melting-boiling point	2
	Total		**16**
Biology	Sea creatures: Sponges, molluscs, echinoderms, …fish	Classification of living things	8
	Fish skeleton	Fossils, Evolution	8
	Fishes	Environmental education	2
	Total		**18**
Physics	Ships, weapons, air pumps, submarine	Pressure/ Liquid pressure	17
	Binoculars, flashlights	Optics, lenses, refraction of light	16
	Wheels, ships, rudders	Simple machines	11
	Sun, Earth, Moon - positioning, Sextant	Astronomy	10
	Ships	Buoyancy force	9
	Ships, guns, axe, sword	Balance, center of gravity	8
	Guns, cannons	Energy Transformations	8
	Telegram	Frequency -Waves	7
	Ships	Intensity	7
	Compass	Magnetism	7
	Sails	Frictional force	5
	Laying mines parallel to the shore	Sound - sound propagation	5
	Compass	Magnetism	5
	Cogs, cannons, guns	Force move, Oblique shot	5
	Ships, Armors, axe, sword	Durability	4
	Ships	Swimming-Sinking	3
	Clothing selection, armor making	Heat – temperature	3
	Speed	Speed	1
	Toplam		**131**
Geosciences	Simulations	Formation of the earth	2
Disiplinlerarası	Shipbuilding	STEM	2
Nature of Science	Imagination, creativity		1
	Subjectivity		1
	Science, culture and interaction		1
	Observation, inference		1
	Total		**4**

After the maritime museum visit, as a result of the evaluation of the Observe-Explain worksheet, preservice teachers mainly associated the museum with Physics, with fewer links to Chemistry and Biology, and minimal connections to Earth Science, the nature of science, and interdisciplinary studies. In Physics, objects like ships and submarines were tied to pressure, binoculars to optics, wheels to simple machines, and a sextant to astronomy. In Biology, living specimens were linked to classification, and in Chemistry, items like gunpowder and steel were connected to chemical reactions. Overall, associations were made with 18 Physics topics, 4 each in Chemistry and Biology, 1 in Earth Science, and 4 in the nature of science.

Results and discussion

In addition to presenting interesting objects to visitors, museums play an essential role in effective and permanent learning since they provide environments that stimulate imagination and increase creativity, curiosity, interest, and excitement. They are also considered an endless source of information in different fields (Buyurgan, 2004; Gartenhaus, 2000). In this regard, the purpose of a museum visit should not only be to examine the artifacts and objects in the museum, but also to enable the visitor to obtain permanent information and to create changes in their behavior and attitudes (Karadeniz & Okvuran, 2014).

The current study determined that preservice science teachers visited museums for sightseeing before the project implementations. The number of preservice teachers who stated that they use museums as learning areas and see them to gather information is limited, with few using them as learning spaces or for collecting information. This likely stems from their perception of museums as historical and cultural artifact exhibition areas. Studies have also revealed that teachers consider museums as environments where historical artifacts are exhibited because they associate the concepts of museums and historical artifacts (Kara et al., 2020). A study conducted with young people (13-23 age range) determined that museums were associated primarily with history, the past, and then with art and nature. However, it was found that the rate of young people who frequently describe museums as places of learning and obtaining information is twice as high as that of those who consider museums as places where objects are exhibited (Drotner et al., 2017). As emphasized above, before the project, the preservice teachers who participated in the current study had limited thoughts about using museums for educational purposes. However, as seen in the following paragraphs, their views on this issue changed after the project training. These findings

emphasize the significance of promoting the idea that museums can be educational settings, which is one of the project's primary goals.

The study found that preservice teachers had positive and negative opinions about their previous museum visits. They appreciated museums for providing knowledge about the past and creating historical connections. However, they criticized inadequate guidance, insufficient information about exhibits, limited time during visits, and a lack of care in museums. Studies emphasize the importance of guides who provide information and recount stories related to exhibits, as they support learning, facilitate visits, and help students connect with the artifacts (Ateş & Lane, 2020; Best, 2012). Duration is also essential for an effective museum visit; researchers have emphasized that short-term museum visits will not be sufficient for learning to occur in the museum, as they would not ensure the student's active participation. They also stated that the physical characteristics of the museum affect visitors' ability to benefit from the museum, so attention should be paid to features such as comfort, ergonomic layout, use of eye-catching elements, and orientation (Karadeniz & Okvuran, 2014).

It was discovered that while most of the preservice teachers involved in the experiment had museum education courses as part of their undergraduate degrees, very few went to museums as part of the curriculum. Additionally, most agreed that the courses they attended were insufficient in duration, content, and status as elective courses. Researchers emphasized that museum education is an essential part of constructivist education, and it should include pre-museum, in-museum, and post-museum processes, preparation of teaching programs considering the museum conditions, education goals, teaching methods, and materials that are going to be used in the teaching process. (Karadeniz & Okvuran, 2014; Şar & Sağkol, 2013). The quality of teaching in higher education depends on including different types of learning and other experiences in practice. In this context, considering that students learn best by questioning, discussing, collaborating, applying, and producing (Laurilland, 2013; Pavlou, 2022), it becomes clear that there is a need to include museum education courses in teacher training programs as compulsory courses, to enrich the content by including museum visits, and to review the duration of the course.

Museums offer environments for cognitive, physical, affective, and social development (Doğan, 2010), providing reliable sources of new environmental information (Falk & Dierking, 2002; Lasky, 2009). They provide access to science resources outside school and enhance skills in observation, inference, and scientific knowledge (Crawins, 2014). Three elements of museum visits—cognitive (new learning experiences), affective

(likely to have fun), and cultivating favorable attitudes about museums—are also the basis for views held by in-service teachers and preservice teachers (Karnezou et al., 2021). In the current study, most preservice teachers had favorable perceptions of teaching science in museums before the project implementation. They agreed that permanent learning might be accomplished by developing a successful plan and making the concepts concrete. They further suggested that skills might be developed under guidance and that the subject-objective connection could be established. Examining artifacts and engaging in related science activities affected preservice educator perspectives on museums. They realized the purpose and scope of museums and began recognizing them as teaching environments. Consequently, all preservice teachers expressed interest in teaching science at museums, believing that such practices, with interdisciplinary connections, would promote effective learning, help concretize information, and foster engagement and discovery.

Before the project training, the study showed preservice teachers struggled to connect science subjects with museum objects. However, their views on the relationship between museums and science education improved after the training. The activities in the project helped them establish connections between science and museums. Initially, most teachers linked science in museums to biology, physics, and chemistry, with a few making interdisciplinary connections. They are primarily associated with biology topics like anatomy, living organisms, and evolution, followed by physics topics such as astronomy, pressure, and simple machines, with a few chemistry connections.

The studies to bring scientific understanding to societies emphasized that archaeological museums have an essential role in understanding and disseminating science (Copley, 2010; Georgopoulou et al., 2021). In this context, it is thought that science will be more accessible to museum visitors by integrating it into archaeological exhibitions and presenting it within the specified scope. As a result of a study determining the opinions of curators regarding the way science is presented in archaeological museums, it was determined that all participants agreed that archaeological museums can be an effective place for the exhibition of science. In addition, scientific topics presented in existing archaeological museums are mainly related to radiocarbon dating, skeletons, bones and diseases, stratigraphy, geophysics, plants and animals (Copley, 2010).

The objects exhibited in archaeological museums can be associated with natural science concepts because they provide visual and tactile stimuli from past cultures (Georgopoulou & Koliopoulos, 2017). In the current study,

preservice teachers primarily linked the Archeology Museum to the field of chemistry before visiting and engaging in related activities. They could not form strong connections with the fields of biology, physics, and earth science.

After subject-specific analysis, these associations were discovered they be related to the subjects of matter, chemical reactions, minerals, acid-base in the field of Chemistry, balance and simple machines in the field of Physics, living things and fossils in the field of Biology, and natural disasters and rocks in the field of Earth Sciences. Following their investigation of the artifacts in the archeology museum and carrying out science activities related to these objects, they mainly established connections with the field of Chemistry, consistent with the findings from their pre-museum visits and museum activities. They also established similar connections in the fields of physics and biology. However, they could also make connections between disciplines and different fields. In studies conducted on associating the objects exhibited in archaeological museums with contemporary scientific knowledge, a relationship between the objects and teaching objectives was established, educational study plans were developed, and the usefulness and necessity of these studies were emphasized (Georgopoulou & Koliopoulos, 2017; Georgopoulou et al., 2022). Other studies revealed the importance of this kind of study for primary and secondary school students. (Külcü &Hürmüzlü, 2013; Nikita et al., 2022). In one of these studies, an Archaeological Science Class Activities guide was prepared for primary and secondary school students on the sub-fields of archeology: In activities related to osteoarchaeology human skeleton and bone types, in activities related to zooarchaeology, domestic and wild animal species, in activities related to archaeobotany, nutrition and various seeds, in ceramic activities the properties of clay, in archaeometallurgy activities the properties of metals and in glass activities, glass making techniques were the focal point (Nikita et al., 2022). These studies demonstrate that archaeology can be integrated with subjects like chemistry, geology, biology, and mathematics across educational levels. For example, stone artifacts and minerals relate to chemistry and geology, while animals depicted on objects connect to biology (Segal & Segal, 2019). Following the museum visit and activities, the study discovered that preservice teachers primarily linked museum objects to physics, followed by chemistry, and least to biology and earth sciences. Compared to initial associations, preservice teachers connected to more topics within each discipline, suggesting that the project helped preservice teachers integrate archaeology with science subjects. Since archaeology connects biology, chemistry, geology, physics, history, and astronomy (Moe, 2011), the project training enabled teachers to recognize this integration more clearly. This result is also

significant since it is one of the project's main objectives. As a result of studies integrating archeology into science education, it has been found that students can make a connection between the interpretation of artifacts and contemporary scientific knowledge, which also supports this result (Díaz, 2016; Georgopoulou & Koliopoulos, 2017; Moe, 2011). It is also emphasized that implementing a holistic education program in the archaeological museum can effectively gain scientific knowledge (Georgopoulou et al., 2021).

Maritime museums are interdisciplinary in nature; they are associated with fields such as history, archaeology, anthropology, art, and natural sciences to explore the many aspects of the sea and its impact on societies (Garradas & Semedo, 2023). Specifically, it explains various maritime topics, including shipbuilding, navigation, maritime trade, fishing, and how naval warfare affects our world (Davies, 2012). Within the project's scope, before visiting the Maritime Museum, it was determined that the preservice teachers mostly associated the maritime museum-science relationship with physics subjects, and secondly with biology subjects. The association with the discipline of chemistry remains limited. After the museum visit and the science activities, they made more connections, especially with the discipline of physics, by considering and giving examples of the objects in the museum. The number of related topics is much higher than in other disciplines. Considering the structure of maritime museums and the objects exhibited, by associating physics subjects with the objects, preservice teachers considered studies that can explore maritime-related issues. In their associations with biology subjects, it is evident that they thought the sea creatures exhibited in maritime museums. However, although the association made with the environmental issue in the current study is minimal, it is suggested in a study that it can also be associated with the impact of pollution and climate change on the sea (Garradas & Semedo, 2023). Studies on the use of maritime museums as teaching environments are limited. However, it has been revealed that their relationship with science can be established due to the study.

As a result of the study, the project assists preservice science teachers in developing connections between science subjects and museum artefacts and in perceiving museums as places to teach science. However, it is limited to the archaeology and maritime museum. It may be suggested that similar training be held in various museums related to science subjects. In addition, considering the importance of out-of-school learning environments for science courses, it is essential to conduct practical studies in teacher training programs to provide science education in different types of museums.

Limitations of the study

The most significant limitation of this study was the earthquakes that occurred on February 6 in the city where the project was carried out. There were disruptions in the execution of the project due to the twin earthquakes that happened on the first day of the project, which was planned to be carried out between 6 and 11 February 2023, and due to these events, some schedule changes were made. For this reason, the lesson plans that the preservice teachers were supposed to implement could not be implemented, and the plans were delivered after the project, and by some of them. Despite all the adversities, preservice teachers wholeheartedly participated in the activities carried out in the project and tried to fulfil their duties.

The authors declare that all declarations regarding funding, ethics, conflict of interest, and data availability are provided below.

Acknowledgments | *The authors gratefully acknowledge TÜBİTAK for its financial and institutional support throughout the implementation of the project. The authors also sincerely thank all participants for their valuable contributions and cooperation during the data collection process.*

Funding | *The project was evaluated by the panelists in line with the relevant legislation of the "2237-A Scientific Education Activities Support Program" carried out under the responsibility of the TÜBİTAK Scientist Support Programs Directorate (BİDEB) and was supported by the decision of the relevant Group Executive Board of BİDEB. Project Name: Exploring the Power of Science in Museums; Grant Number: 1129B372201161*

Ethics statements | *All procedures performed in this study were carried out in accordance with the ethical standards of the TÜBİTAK Scientist Support Programs.*

Conflict of interest | *The authors declare that they have no conflict of interest.*

Informed consent | *Informed consent was obtained from all individual participants included in the study.*

Data availability | *The data that support the findings of this study are available from the corresponding author upon reasonable request.*

Statement on the Use of AI Tools | *The Grammarly AI tool was used in the final editing of our English language proofreading. No AI tool was used in any of the other sections.*

References

Altınok, M., A., & Tunç, T. (2013). Bilimsel süreç becerileri bağlamında geçmiş Türk fen programlarının karşılaştırmalı incelenmesi. *Türk Fen Eğitimi Dergisi, 10*(4), 22-55. https://doi.org/10.36681/, https://www.tused.org/index.php/tused/article/view/390/900

Ateş, A., & Lane, J. F. (2020). Analysing school-museum relations to ımprove partnerships for learning: A case study. *Education and Science, 45*(201), 231-246. https://doi.org/10.15390/EB.2019.8017

Anderson, D., Lucas, K. B., & Ginns, I. S. (2003). Theoretical perspectives on learning in an informal setting. *Journal of Research in Science Teaching, 40*(2), 177-199. https://doi.org/10.1002/tea.10071

Best, K. (2012). Making museum tours better: Understanding what a guided tour really is and what a tour guide really does. *Museum Management and Curatorship, 27*(1), 35–52. https://doi.org/10.1080/09647775.2012.644695

Buyurgan, S. (2004) Effective learning at the museum. *Journal of Cultural Research in Art Education, 22*, 99-115

Copley, M. S. (2010). Towards presenting scientific research in archaeology museums. *Museum Management and Curatorship, 25*(4) 383–398. https://doi.org/10.1080/09647775.2010.525404

Cooper, D. (2003). A virtual dig-joining archaeology and fiction to promote critical and historical thinking. *The Social Studies, 94*, 69-73. https://eric.ed.gov/?id=EJ770154

Crawins, C. L. (2014). *An exploration of object and scientific skills-based strategies for teaching archaeology in a museum setting* [Unpublished master's thesis]. Utah State University Logan. https://digitalcommons.usu.edu/etd/2774

Davies, S. (2012, May). Maritime museums: Who needs them?. *Nalanda-Sriwijaya Centre Working Paper, (*11). http://www.iseas.edu.sg/nsc/documents/working_papers/nscwps011.pdf

Díaz, J. G. (Coord.). (2016). *Scientific literacy at school. An inquiry about archaeology in the classroom. Project.* http://www.csicenlaescuela.csic.es/scilit/pdf/guides/scilit-an-inquiry-about-archaeology.pdf

Doğan, Y. (2010). Primary school students' benefiting from museums with educational purposes. *International Journal of Social Inquiry, 3*(2), 137–164. https://dergipark.org.tr/en/pub/ijsi/issue/17731/185717

Drotner, K., Knudsen, L.V., & Mortenesen, C.H. (2017). Young people's own museum views. *Museum Management and Curatorship, 32*(5), 456-472. https://doi.org/10.1080/09647775.2017.1368032

Eres, Z. (2018). Arkeolojik kazı, koruma, sergileme ve toplum ilişkisi- Kırklareli'nde tarih öncesi arkeolojik alanlar üzerinden bir deneyim. *Azərbaycan Arxeologiyası, 21*(1), 110-151. http://dspace.khazar.org/handle/20.500.12323/3848

Falk, J. H., & Dierking, L. D. (2002). *Lessons without limit: How free-choice learning is transforming education*. AltaMira Press.

Fitriani, R., Al Rasyid, M., Sabekti, A. W., & Putri, S. D. (2024). Analysis of chemistry education students' level of understanding of the basic concepts of science education in the perspective of sustainable maritime education. In *SHS Web of Conferences* (Vol. 205, p. 05005). EDP Sciences. https://doi.org/10.1051/shsconf/202420505005

Garradas, C., & Semedo, A. (2023). Potential of maritime museums for heritage education. *Didáctica de las Ciencias Experimentalesy Sociales, 44*, 51-70. https://doi.org/10.7203/dces.44.26418

Gartenhaus, A. R. (2000). *Creative thinking and museums* (R. Mergenci & B. Onur, Trans.). Ankara University Press.

Geiger, B. F. (2004). Teaching about history and science through archaeology service learning. *The Social Studies, 95,* 166-171. https://doi.org/10.3200/TSSS.95.4.166-171

Georgopoulou, P., & Koliopoulos, D. (2017). Archaeological museums as environments of informal and non–formal science and technological education: The case of Educative Islets. In V. Ferrara (Ed.), *Proceedings of the EdMuse Conference*, *Roma, Italy: Sapienza Università di Roma,* 100–103. https://www.academia.edu/34226943/Archaeological_museums_as_environments_of_informaland_non_formal_science_and_technological_education_The_case_of_Educative_Islets

Georgopoulou, P., Meunier, A., & Koliopoulos, D. (2020). *Archaeometry as an interdisciplinary field of exhibition design and non–formal education in the archaeological museum* [Conference presentation]. 13th International Conference on the Inclusive Museum, Lisbon, Portugal. https://cgscholar.com/community/community_profiles/inclusive-museum/community_updates/125919

Georgopoulou, P., Koliopoulos, D., & Meunier, A. (2021). The dissemination of elements of scientific knowledge in archaeological museums in Greece: Socio-cultural, epistemological, and communicational/educational aspects. *Scientific Culture, 7*(1), 34-40. https://doi.org/10.5281/zenodo.4107170

Georgopoulou, P., Meli, K., & Koliopoulos, D. (2022). An interpretive and pedagogical approach of archaeological collections in the light of natural sciences: The notion of science educative ıslet. *Review of Science, Mathematics and ICT Education, 16*(1). 49-75. https://doi.org/10.26220/rev.3818

Griffin, J. (2004). Research on students and museums: Looking more closely at the students in school groups. *Science Education, 88*(S1) 59-70. https://doi.org/10.1002/sce.20018

Hein, G. E. (2004). John Dewey and museum education. *Curator: The Museum Journal, 47*(4), 413-427. https://doi.org/10.1111/j.2151-6952.2004.tb00136.x

Higgins, P. J., & Holm, K. A. (1985). Introduction. In K.A. Holm, & P.J. Higgins (Eds.), *Archeology and Education: A Successful Combination for Precollegiate Students (pp. 1-8).* University of Georgia.

ICOM (International Council of Museums). (2022). Museum definition. https://icom.museum/en/resources/standards-guidelines/museum-definition/

İlhan, Ç. A., Artar, M., Okvuran, A., & Karadeniz, C. (2014). Museum training programme in Turkey: Story of friendship train and children's education rooms in the museums. *Creative Education, 5*, 1725-1732. https://doi.org/10.4236/ce.2014.519192

Jeppson, P. L., & Brauer, G. (2007). Archaeology for education needs: An archaeologist and an educator discuss archaeology in the baltimore public schools. In J. H. Jameson & S. Baugher (Eds.), *Past Meets Present: Archaeologists Partnering with Museum Curators, Teachers, and Community Groups*, (pp.231-248). Springer. https://doi.org/10.1007/978-0-387-48216-3_15

Karadeniz, C., & Okvuran, A. (2014). Müzede bir gece: Ankara Üniversitesi öğrencileri ile Çorum Arkeoloji Müzesi'nde müze eğitimi. *İlköğretim Online, 13*(3), 865-879. https://www.researchgate.net/publication/298093571_A_night_at_the_museum_Museum_education_with_Ankara_University_students_at_Corum_Museum_of_Archeology

Karadeniz, C., & Sivrikaya, G. (2020). Müzeler. In C. Laçin Şimşek, Editor (Ed.), *Fen öğretiminde okul dışı öğrenme ortamları* (pp.19-56). Pegem Yayınevi. https://pegem.net/urun/Fen-Ogretiminde-Okul-Disi-Ogrenme-Ortamlari-61155?srsltid=AfmBOopH1ReC27mUMf0uCLtGP4h3w_ERO--vVQdxo17CauSc5LP1-MJs

Kara, B. , Sak, M., Balçın, M. D., & Mertoğlu, H. (2020). Fen bilimleri öğretmenlerinin müze eğitimi hakkındaki görüşleri. *Akademik Sosyal Araştırmalar Dergisi, 8*(108), 318-346. http://dx.doi.org/10.29228/ASOS.44864

Karnezou, M., Pnevmatikos, D., Avgitidou, S., & Kariotoglou, P. (2021). The structure of teachers' beliefs when they plan to visit a museum with their class. *Teaching and Teacher Education*, *99,* 103254. https://doi.org/10.1016/j.tate.2020.103254

Karul, N., Avcı, M.B., Deveci, A., & Karkıner, N. (2010). Bursa Aktopraklık Höyük'te kültür sektörünün ulması: Çok yönlü bir proje. *TÜBA-KED*

Türkiye Bilimler Akademisi Kültür Envanteri Dergisi, 8, 241-262. https://dergipark.org.tr/tr/pub/tubaked/issue/57432/814200

Karul, N. (2015). Aktopraklık açıkhava müzesi ve arkeoloji okulu. *Arkeoloji ve Sanat, 150*, 11-22.

Kratz, S., & Merritt, E. (2011). Museums and the future of education. *On the Horizon*, *19*(3), 188-195. https://doi.org/10.1108/10748121111163896

Külcü, Ö. T., & Hürmüzlü, B. (2013). Archeo-kid: A project-based learning model (Establishing background for archaeology in childhood and adolescence). *European Journal of Research on Education* Special Issue: Art in Education, 1-6. https://www.academia.edu/9720658/Establishing_background_for_archaeology_in_childhood_and_adolescence

Lasky, D. (2009). Learning from objects: A future for 21st century urban arts education. *Penn GSE Perspectives on Urban Education, 6*, 72-76. https://files.eric.ed.gov/fulltext/EJ869348.pdf

Laurillard, D. (2013) *Rethinking University Teaching: A Conversational Framework for the Effective Use of Learning Technologies*. Routledge, Abingdon-on-Thames. https://doi.org/10.4324/9781315012940

Lau, M., & Sikorski, T.R. (2018). Dimensions of science promoted in museum experiences for teachers. *Journal of Science Teacher Education, 29(*7), 578-599. https://doi.org/10.1080/1046560X.2018.1483688

Letts, C. A., & Moe, J. M. (2009). *Project archaeology: Investigating shelter*. Montana State University, Bozeman.

Mercin, L. (2017). Müze eğitimi, bilgilendirme ve tanıtım açısından görsel iletişim tasarımı ürünlerinin önemi. *Milli Eğitim Dergisi*, *46*(214), 209-237. https://dergipark.org.tr/tr/pub/milliegitim/issue/36135/405933

Moe, J. (2011). *Conceptual Understanding of Science Through Archaeological Inquiry*. [Unpublished doctoral dissertation]. Montana State University.

Nikita, E., Bonner, L., & Rehren, T. (2022). Archaeological science classroom activities: A free multi-lingual pedagogical resource in archaeological science. *Journal of Archaeological Science Reports, 45*. https://doi.org/10.1016/j.jasrep.2022.103583

Onur, B. (2012). *Çağdaş müze eğitim ve gelişim*. İmge Kitabevi.

Owen, T. D., & Steele, J. N. (2005). Perceptions of archaeology amongst primary school aged children, Adelaide, South Australia. *Australian Archaeology, 61*(1), 64-70. https://doi.org/10.1080/03122417.2005.11681822

Pavlou, V. (2022). Museum education for pre-service teachers in an online environment: Challenges and potentials. *International Journal of Art and Design Education*, *41*(2), 189–354 https://doi.org/10.1111/jade.12404

Roy, N. (2019). Making a StINK with STEM in the classics classroom: Exploring Ancient Roman writing through experimental archaeology. *The Journal of Classics Teaching, 20*(40), 14-19. https://doi.org/10.1017/S2058631019000278

Şar, E., & Sağkol, T. (2013). Eğitim fakültelerinde müze eğitimi dersi gerekliliği üzerine. *HAYEF Journal of Education*, *10*(2), 83-90.

Segal, R., & Segal, D. (2019). *Educational and Experiential Activities, for Students and Teachers of Mathematics and Sciences, in a Classical Museum of Archeology*. International Conference: The Future of Education, Florence, Italy.

Smardz, K. E. (1989). Educational archaeology: Toronto students dig into their past. *History and Social Science Teacher, 24*(3), 148–155. https://scispace.com/papers/educational-archaeology-toronto-students-dig-into-their-past-2sjnh7s0zj

Sönmez, D., & Ozturk, N. (2022). Preparing to teach in informal settings: Preservice science teachers' experiences in a natural history museum. *International Journal of Science Education, 44*(8), 1-21. https://doi.org/10.1080/09500693.2022.2149285

Tezcan Akmehmet, K. (2014). Eğitim ve müzeler. In R. Yağcı, & S. Gündüz Küstü (Eds.), *Müzeler, Oyunlar, Oyuncaklar ve Çocuklar* (1st ed., pp.155-161). Dokuz Eylül Üniversitesi Yayınları.

Türkmen, H. (2018). Ortaokul öğretmenlerinin sınıf-dışı ortamlarda öğretime bakış açıları. *Ege Sosyal Bilimler Dergisi / Journal of Ege Social Science, 1* (1), 12-26.

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Sage.

Yüksek Öğretim Kurulu. YÖK. (2018). *Öğretmen yetiştirme lisans programları.* www.yok.gov.tr