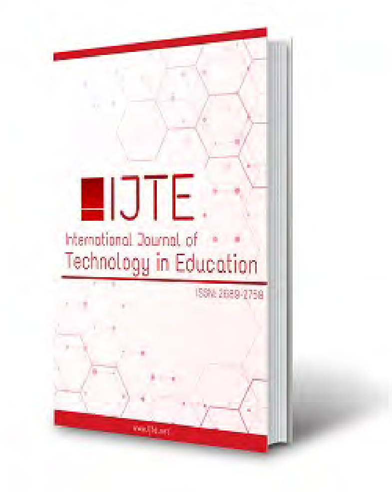

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Abstract

Virtual solutions of museums can be notably used to promote distance learning activities by providing information about their collections. However, the effective use of this potential depends mainly on the exact alignment of the learning activities with the educational goals. For this purpose, this study focuses on the analysis of pre-service teachers' activity designs based on virtual museum visits for out-of-school learning environments. Within the scope of the case study design, 40 activity plans developed by pre-service teachers for elementary mathematics, science, and classroom teaching were examined. The activity designs for selected virtual museums emerged as a result of a semester program. The research findings indicated that the activities emphasized the strategies of supporting learning outcomes, the guidance process for students in the virtual museum environment, and the engagement of the student with the virtual environment. Based on this, the study revealed that using virtual museums as a teaching tool for pre-service teachers supports teachers' knowledge and skills of the activity design.

Introduction

While learning through museums or artifacts in museums enriches the learning process of children in a constructivist manner, it contributes significantly to cognitive development, as described in Piaget and Vygotsky's theory (Haensly, 1999). Additionally, museums form a learning ecosystem designed for children with their institutional structure and teams of experts (National Research Council [NRC], 2015). Exhibition spaces in museums host numerous thematic collections, such as archeology, art, anatomy, mathematics, and technology. In this way, they create an enriched educational environment for learning subjects and concepts in the curriculum. Science-themed museums, for example, aim to make clearer sense of scientific phenomena and to have visitors discover the science underlying the exhibited work. Allen (1997) states that interactive objects in science-themed museums (e.g., the color shadow exhibition) allow for many activities related to scientific inquiry; consequently, science can be understood more clearly. Similarly, Kreuzer and Dreesmann (2017) reveal that students grasped subjects such as evolutionary science after the teacher conducted lessons through biology collections in museums. Fenichel and Schweingruber (2010) state that museums serve five common purposes in relation to learning, namely:

i. engaging visitors in various ways, including physical, emotional, and cognitive

ii. encouraging visitors to interact directly with the phenomenon of the natural and designed world in mainly learner-driven ways
iii. providing versatile and dynamic depictions of science
iv. developing prior knowledge and interests of visitors
v. providing visitors with an opportunity for an important choice and control over whether and how they will interact

In the literature, learning in museums is often classified as informal or out-of-school learning, entirely outside of any educational institution (Fenichel & Schweingruber, 2010; Salmi, 2012). In this respect, the literature on museum education or learning in museums is quite extensive. However, most museums today have developed virtual solutions as an alternative to classical display approaches. According to Schweibenz (2004), the main idea behind virtual museums is to build a digital extension of museums over the Internet (a museum without walls), and this idea goes as far as creating a single virtual museum database that can bring together digital objects from museum collections all around the world. Inevitably, the classical museology understanding will gradually change form and virtual museums will become more effective. Considering Turkey alone, the Ministry of Culture and Tourism has made available the virtual presentations of 33 prominent museums and archeological sites on its official website (https://sanalmuze.gov.tr/) as of April 2021.

When considered on a global scale, a large number of virtual museums have made access to their collections behind closed doors available, independent of time and space. This way, virtual users who would have never been able to visit a particular museum in person can easily interact with digital museum objects (Schweibenz, 2004). According to Kavanagh et al. (2017), museums provide attendees with access to rare or geographically separated artwork, granting visitors the opportunity to explore the content more with various design elements such as gamification. For this reason, researchers state that digital learning objects in virtual museums will be increasingly used in education. Besides virtual museums' envisaged potential in education, studies also report some limitations to their use. For example, Paquin (2015) stated that a many teacher had difficulties in integrating virtual museums into teaching; consequently, they did not prefer using them in their classes. Kavanagh et al. (2017), on the contrary, state that teachers generally use virtual museums to motivate students, and that they have a very narrow understanding of integrating virtual museums with constructivist pedagogy, collaborative work, and gamification. For this reason, how virtual museum objects can be used effectively by teachers is still unclear.

Integration of Virtual Museums into Teaching Processes

Museums, which are home to scientific, cultural, and natural heritage, have great potential as an effective learning environment for students to make sense of scientific facts. Museums allow children to interact with natural objects. They create opportunities for scientific inquiry (Harlen et al., 2003). They contribute to the scientific knowledge structure, social interaction support, permanence of what has been learned, and formation of a cultural identity (Martin, 2004). Collection ideas and concepts brought together as a result of a thematic classification approach provide students with a systematic observation opportunity. In this way, teachers can practically discuss and asks questions about natural phenomena with learning materials, the alternatives to which are difficult to find in schools (Gutwill & Allen, 2012).

In addition to creating collections, museums convey the scientific data regarding objects to their visitors either through artifacts or through explanations by the museum staff. Thus, students obtain information to collect samples and data and have the opportunity to observe the changes and interactions in natural areas or between natural elements (Pease et al., 2020). In this aspect, the rich exhibition spaces hosted by museums support inquiry at many stages, including observation, exploration, and data collection, which fosters inquiry as a learning approach that involves the process of exploring the natural or material world and leads to asking further questions, making discoveries, and studiously testing these discoveries in search of better understanding (NRC, 2000a). One of the important variables for effective inquiry in museums is the learner's level of interaction with the museum materials. Vartiainen and Enkenberg (2013) indicate that teachers generally prefer to plan learning processes with museum materials or provide the freedom of choice to support inquiry; however, this is insufficient for inquiry. Researchers state that teachers should use various tools for creating scaffolding strategies to support the learning process, while focusing on social interaction and questioning.

On the contrary, much more interaction can be established in virtual museums than through classical museum tours. In the early studies on virtual museums, usability and software problems or negative effects of interface design on interaction quality and readability were reported (Hsieh et al., 2010). However, in the following years, such problems were gradually resolved with the technological development. For example, Apostolellis and Bowman (2014) state that groups do not have enough time to interact with the content in classical museum tours and they generally obtain information passively from the objects in the museum. Virtual solutions, conversely, have shown that visitors can interact more with the museum content and these solutions support collaborative learning. Today, virtual reality or augmented reality technologies are used for content transfer in virtual museums to maximize the interaction of participants with museum materials. Such technologies distinctively provide benefits for users in creating attractive environments, supportive in terms of contextual and spatial skills, and visualizing and concretizing concepts.

Therefore, the use of these technologies for science courses is shown as innovative strategies for students to access scientific knowledge and gain experience in inquiry. Meanwhile, the understanding of exhibition in virtual museums can be supported pedagogically by various scaffolding strategies. For example, according to Styliani et al. (2009), a substantial portion of virtual museums combines interaction, experience, and learning considering the basic principles of constructivism and gamification. Thus, visitors are able to interact with digital museum objects rather than merely observing, and form the information themselves. Simultaneously, targeted and directed activities with mini-games, such as puzzles and treasure hunts can be used to encourage visitors to explore the virtual museum more deeply (Angeloni et al., 2012).

Studies show that teachers can effectively use digital objects in virtual museums for planned classroom learning activities in primary and secondary education (Okolo et al., 2011; Paquin, 2015). According to Kersten et al. (2017), virtual museums should be used as teaching materials in the context of museum education, as well as supporting museum visitors to examine additional materials or deepen their knowledge before or after the actual visit. They exemplified the transfer of virtual museums to education through the virtual solution of the "Alt-Segeberger Bürgerhaus" museum, which is a historical townhouse, and created an interactive educational environment on city development and the housing tradition in the city of Bad Segeberg. In this way, it is possible to gain historical knowledge, develop awareness, and understand the importance of historical and cultural values and attitudes with the practices to be carried out through virtual museums (Uztemur et al., 2019).

As stated in the studies, the use of virtual museums in educational environment requires teacher competencies in the context of information technologies. In a teaching process using the virtual museum, the learners cannot be expected to take responsibility for the learning process by themselves. Accordingly, for a teaching technique to be prepared through virtual museums, planning that can guide students in a digital environment, support observation and data collection, create a product, and support interaction with peers should be included. Teachers acquire many competencies in the context of field knowledge, effective pedagogical practices, and advanced technologies required for planning a course within the framework of pre-service teacher training or subsequent professional development. According to Desimone (2009), teachers reflect this progress toward students' learning process through instructional practices. Moreover, Davis (2006) states that teachers should have the knowledge and skills to adapt the curriculum materials; hence, pre-service teachers should have beginner level qualifications for this authentic teaching task.

Lesson plans developed as direct data sources that can reveal pre-service teachers' basic ideas about teaching and their perceptions about inquiry are given indication (Newman et al., 2004). For this reason, through the analysis of lesson plans, pre-service teachers can provide information about how they structure a lesson, which methods and strategies they aim to guide students with, and which tools they aim to use in an integrated manner with the subject. Davis (2006), in his study on the criticism of lesson plans as primary school teacher candidates' curriculum materials, revealed that pre-service teachers might have difficulties in transferring science content to curriculum materials.

Kilicoglu (2019), by contrast, showed that pre-service teachers could be inadequate and inconsistent in the planning skills of mathematics courses. Pre-service teachers specializing in lesson plans, which are curriculum materials, can support the successful implementation of innovative teaching approaches such as inquiry (Forbes & Davis, 2008), an integrated understanding of pedagogy and content (Beyer & Davis, 2012), and overcoming the pedagogical challenges that they may encounter while planning (Minken et al., 2021). Alternatively, lesson plans as exemplars of lessons can reveal the teacher's pedagogical character, the pre-example of teaching or the teacher's technological knowledge for the professional development of a learning community (Morales et al., 2020). According to Namdar and Kucuk (2018), examinations on lesson plans can provide pre-service teachers with experience in many subjects, such as creating science-based questions for an inquiry-based course, alternative assessment and evaluations, data collection, and analysis.

In summary, with their rich and comprehensive collections, virtual museums serve as an easily accessible learning environment that can be integrated into education programs. However, the effective use of virtual museums as a teaching tool depends on the engagement of the student with the learning environment. The main role in this interaction falls on the teachers who are expected to guide learning. From this viewpoint, this study focuses on the examination of activity plans created at the end of a program on how activities can be conducted in virtual museums in pre-service teacher education. This study reveals pre-service teachers' understanding of an inquiry-based teaching process through the collection of ideas and concepts of virtual museums through activity plans.

Methods

This study employed a case study method, which examines how the pre-service teachers designed the activities to be conducted in virtual museums. Patton (2015) has suggested using a case study to question the conception and understanding of why a phenomenon occurs, rather than identifying empirical generalizations. In this context, the focus of case studies was to provide a deep understanding of a case such as an activity or process (Creswell, 2012). The case determined within the scope of this study included the activity plans prepared by the pre-service teachers at the end of an implementation related to the use of virtual museums in teaching.

Study Group

The study group consisted of 40 next-to-last year pre-service teachers majoring in the classroom teaching (f = 8), primary school mathematics (f = 16), and science (f = 16) courses. Participants were included using the convenience sampling method. In convenience sampling, the researcher determines the participants according to their willingness and availability for the research (Creswell, 2012). The reason for choosing this sampling method was that the implementations of this study are carried out within the scope of a course on current practices in educational technologies included in the programs of education faculties throughout Turkey.

Pre-service teachers can graduate after a four-year training period in education faculties. In the context of the Turkish education system, classroom teachers conduct lessons in life sciences, science, mathematics, and music from the 1st to 4th grades in primary school. Mathematics and science teachers, on the contrary, conduct their specialty field lessons at the grade levels between the 5th and 8th grades. Every pre-service teacher participating in the study is a next-to-last year candidate teacher. In this context, they have taken both specialized field and pedagogy courses based on their departments in the previous years. Participants in the study group did not receive any training on how teaching can be conducted in virtual museums throughout their education lives or did not experience a good example of practice.

Intervention

Research applications were carried out in approximately one semester (the fall semester: 14 weeks). During this period, both theoretical and practical content was presented to the participants with two-hour lectures per week. Practices in the program consisted of the modules of (1) use of virtual museums in the educational context, (2) virtual museum examples, (3) use of scientific inquiry-based approaches in virtual museums, (4) activity design in virtual museums, (5) measurement and evaluation activities in virtual museums, and (6) individual activity design for selected museums by participants. In the last module, the participants were granted a period of four weeks to create their activity plans. During this period, four meetings were organized with the participants where discussions and interviews were conducted.

Practices within the scope of six modules were carried out by the first author of this study through distance education. In this process, the participant and practitioner used an online platform on which they were registered. Each practice carried out on this platform was transformed into video recordings. Participants could return to the previous weeks and watch the practices whenever they desired. Additionally, short learning tasks were prepared for the participants for each week. For example, participants were asked to prepare a form to determine the prior knowledge and experience of students in virtual museums using Web 2.0 tools. Through the examination of this form, individual feedback was provided to the participants directly, and effective application of the form was attempted in the context of the learning outcomes of the participants.

Data Sources

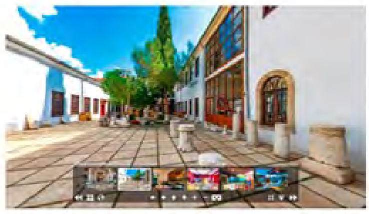
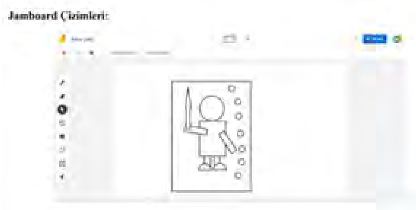
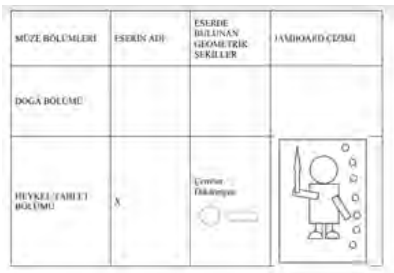
The data sources of the research were the activity plans created by the participants during the practical process and the reflective forms created at the end of the practice. As the situation determined within the scope of the study was the activity plans created by the pre-service teachers at the end of an implementation related to the use of virtual museums in teaching, reflective forms were used to examine the relevant situation in detail and depth.

The participants were not provided with a standard template for activity plans because classroom, mathematics, and science lessons can be taught with different teaching approaches or models in the curricula of the Ministry of National Education. For example, the science curriculum (in 4th–8th grades) is based on the research and inquiry approach and the Ministry emphasizes the use of the 5E inquiry-based instructional model in lessons (Ministry of National Education [MoNE], 2018a). The mathematics curriculum, on the contrary, provides flexibility to teachers on the condition that the learning approach is within the framework of the learning outcomes (MoNE, 2018b).

Based on this situation, the participants were asked to create activity plans specific to their fields of expertise using the knowledge and skills they gained during the practical process. The activity plans were created as online texts and the links for the museums where each practice will be conducted, worksheets (if any), and other attachments were included in the created activity file. To present the structure of the activities in more detail, the basic teaching practices of an activity plan analyzed in Table 1 are presented.

Reflective forms were used to obtain detailed information about the activity plans prepared by the participants. These forms were filled in online by the participants at the end of the practical process. The relevant form consists of three questions. These questions are as follows: (1) What was the focus of your activity?, (2) how did you support your students in the virtual museum tour?, and (3) how do you evaluate your activity as a teacher?

Table 1. Elementary Mathematics Teacher Candidate Designs Activity Example

General Information	Program: Math teaching Museum: Virtual Solution of Museum of Muğla, Turkey The collection included in the activity: Archeology Subject content: Geometric solids	
Instructional practice I	Organization: Before the museum tour Web 2.0 tool used: Google forms Goal: Understanding students' expectations of the trip	
Instructional practice II	Organization: During the museum tour Virtual museum: Virtual Museum of Muğla, Turkey Goal: Informing, including a brief introductory presentation	
Instructional practice III	Organization: During the museum tour Web 2.0 tool: Google Jamboard Goal: Providing student interaction with the virtual museum content and offering a task to their peers to find artifacts with geometric objects	
Instructional practice IV	Organization: During the museum tour Tool: Observation Form Goal: Data collection (Finding the digital work and its collection; Saving the work information on the form)	
Instructional practice V	Organization: After the museum tour Web 2.0 tool: Canva Goal: Product creation; Design creation	

Data Analysis

The inductive approach was used in the analysis of the data obtained in line with the study objectives. Inductive approach focuses on allowing the emergence of frequent, dominant, or important themes inherent in the raw data of the research (Thomas, 2006). In this context, content analysis was used in the data analysis process (Miles & Huberman, 1994). The content analysis followed the steps shown in Figure 1, adapted from Zhang and Wildemuth (2009):

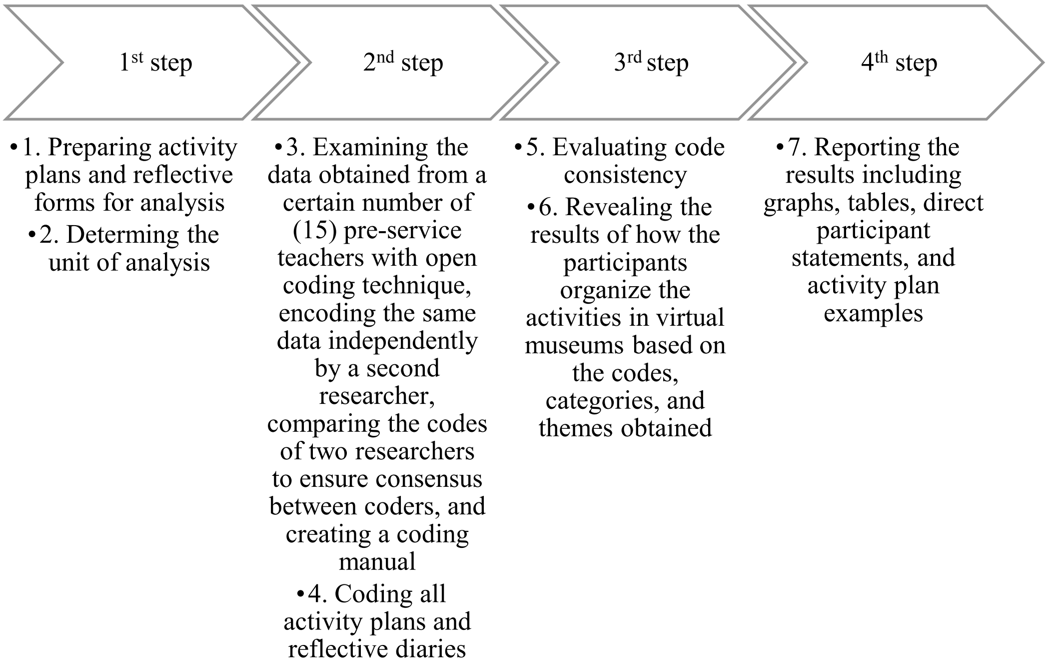


Figure 1. Steps Followed in Content Analysis

To ensure the study's credibility, the reflective forms and activity plans were examined and the data source triangulation and the planning, execution, and data analysis stages of the research were assessed by a qualitative research methods expert researcher other than the authors (peer debriefing) (Creswell, 2012). Additionally, during the data analysis process, a second researcher reviewed all data according to the codes obtained from open coding. At the end of this process, the consistency index between raters regarding the coding of the two researchers was examined and the coding consistency was evaluated. To ensure research transferability, qualifications such as participant characteristics, environment, and research process were attempted to be presented openly, clearly, and in detail (Guba & Lincoln, 1982).

The study findings were summarized into tables and graphics within the scope of each theme and category obtained from data analysis. In the presentation of the findings, the descriptive information of the participants was anonymized as follows: C1–C8 for classroom teaching, M1–M16 for primary school mathematics education, S1–S16 for science teaching; for the data sources, A for the activity form and R for the reflective form were used as the determined codes. For example, while S7-A defines the data obtained from the activity plan of the participant number 7 in the science teaching program, S7-R is used to express the data obtained from the reflective form of the same participant.

Results

The analyses discuss the pre-service teachers' understanding of an inquiry-based teaching process through the collection ideas and concepts of virtual museums under two headings, namely, general descriptive features reflected in activity plans and activity organizations in the context of instructional practices.

General Descriptive Features regarding Virtual Museums and Their Transfer to Teaching Processes

For an inquiry-based education in classroom, Table 2 presents primary school mathematics and science teaching, the virtual museum chosen by the pre-service teachers, the collection ideas in the museum, and the subject content in the curriculum to which the relevant collection is associated.

Table 2. Using Virtual Museums in Activity Plans

Program	Museum (f) *	The collection included in the activity (f)	Subject content (f)
Classroom teaching	Ethnography Museum of Ankara, Turkey (f = 1) Panorama History Museum, Turkey (f = 1) Virtual Museum of Muğla, Turkey (f = 2) Zeugma Mosaic Museum, Turkey (f = 1) Istanbul Toy Museum, Turkey (f = 1) The Astronomy Museum Istanbul, Turkey (f = 1) Ephesus Virtual Museum, Turkey (f = 1)	Ethnography (f = 1) Archeology (5) Toy (f = 1) Astronomy (f = 1)	City history (f = 1) General museum tour (f = 7)
Primary Mathematics Teaching	Thales Museum of Mathematics, Turkey (f = 2) Museum of Turkish and Islamic Arts, Turkey (f = 1) Virtual Museum of Muğla, Turkey (f = 2) Ethnography Museum of Ankara, Turkey (f = 1) Rosicrucian Egyptian Museum, USA (f = 1) Istanbul Rahmi M. Koc Museum, Turkey (f = 2) National Gallery of Art, USA (f = 1) The British Museum, UK (f = 2) Hermitage Museum, Russia (f = 1) Karsiyaka Science Museum, Turkey (f = 1) Metropolitan Museum of Art, USA (f = 1) Pinacoteca di Brera, Italy (f = 1)	Mathematics (f = 2) Archeology (f = 6) Ethnography (f = 1) Technology and history of science (f = 2) Art (f = 5)	Creating a chart (f = 1) Mathematics and basic concepts (f = 3) Geometric solids (f = 8) General museum tour (f = 4)
Science Teaching	Oxford University Museum of Natural History, UK (f = 1) Museum of the History of Science and Technology, Turkey (f = 1) Natural History Museum London, UK (f = 3) Sehit Cuma Dag Natural History Museum, Turkey (f = 1) Veterinary Anatomy Museum Ankara: Turkey (f = 1) Virtual Museum of Muğla, Turkey (f = 1) Pamukkale Travertines (Hierapolis), Turkey (f = 1) Istanbul Rahmi M. Koc Museum, Turkey (f = 2) London Science Museum, UK (f = 1) The Astronomy Museum Istanbul, Turkey (f = 1) National Museum of Natural History, USA (f = 1) Smithsonian National Museum of Natural History, USA (f = 1) Science and Technology Museum Bursa, Turkey (f = 1)	Natural history (f = 7) Science and technology (f = 5) Animal Anatomy (f = 1) Archeology (f = 1) Geological area (f = 1) Astronomy (f = 1)	Extinct animals (f = 3) Optical (f = 1) Celestial bodies (f = 3) Biodiversity (f = 5) Technology (f = 3) Geological structures (f = 1)

* (f) indicates the number of lesson plans in which the reference is coded.

When the descriptive analysis in Table 2 is examined, it is seen that 40 activity plans have been developed for 26 different domestic and international virtual museums. Domestic museums offer Turkish and at least one language support of English and include Turkish and English texts on the artifacts. English was used to practice on international museums, and it was determined that these museums were used effectively even though Turkish language packages were not available in them. Second, in the context of collection ideas in virtual museums, there are museums such as The British Museum, which contain mixed collections, as well as thematic museums (e.g., Veterinary Anatomy Museum Ankara). To make sense of the guidance strategies that the pre-service teachers reflected on their activity plans, each museum was examined during the analysis. The museums used comprised large complexes consisting of numerous exhibition areas where students could easily get lost (e.g., the Natural History Museum London, UK), as well as those with one or two halls (the Virtual Museum of Muğla, Turkey) that students can visit in a short time. A pre-service teacher expressed the reason for using a large museum complex in their lesson plan in the reflective forms as follows:

> I have focused on observing plants, animals, fungi, and microscopic creatures in the activity I will conduct in the virtual museum. It is not possible to bring all of these species to the classroom, but there are many species in the Natural History Museum London. I can present many examples of each species to the students. (S16-R)

On the contrary, in addition to the classical museology understanding, the virtual representations of natural areas and ancient cities (e.g., Pamukkale Travertines and Hierapolis) included in the UNESCO World Heritage list are also included in the planning. Activity designs generally fall under two basic categories, focusing on teaching a particular subject content using virtual museums or focusing directly on a virtual museum tour. When the tendency toward the categories within the framework of the programs is evaluated, it is seen that the plans regarding science and mathematics teaching are clearly prepared for specific subjects, and the plans regarding classroom teaching aim directly for virtual museum tours. In the context of the subject contents aimed to be taught, it was determined that the participants focused on subjects such as extinct animals, optics, biodiversity, and geological structures for science teaching, and mainly geometric solids, mathematics, and basic concepts for mathematics teaching. In planning for mathematics teaching, associations with subject content were explained in the reflective forms with the following expressions:

> I focused on enabling students to explore the translation and reflection movements from tile arts and the motifs on wooden works through the virtual museum (the Ethnography Museum of Ankara) using research and discovery methods. I associated polygons with successive translations and reflections in the motifs. (M4-R)

It has been determined that such approaches are closely related to the learning outcomes in the curricula specific to the disciplines. This situation is clearly demonstrated in the activity objectives. For example, a pre-service science teacher determined that the aims of the activity he planned to carry out at the Veterinary Anatomy Museum of Ankara were (1) *observing the entities forming the support and movement system* and (2) *examining the skeletal system of vertebrate animals* (S5-A). The aims of a mathematical activity planned to be conducted in the National Gallery of Art were (1) *associating polygons with different disciplines* and (2) *distinguishing polygons on different shapes* (M8-A). In the activity a pre-service classroom teacher planned to organize in the

Istanbul Toy Museum, the purpose was stated as *organizing a virtual trip to the toy museum* (C5-A). The pre-service teachers' approaches to association with the curriculum and their approach to the curriculum in planning were reflected in the reflective diaries with the following statements:

> … my main achievement was in inquiry the importance of biodiversity for natural life. There were extinct animals in the virtual museum (the National Museum of Natural History) that even I did not know about … I thought that a 3D tour of the museum would give students the opportunity to examine these creatures as if they were real … I designed my activity in this way to present my educational goals to the students. (S12-R)

In the plans for classroom teaching, as suggested in the curriculum, there is an approach to museums wherein affective aspects such as gamification and instilling a love for research and observation are prominent. Statements in the coded data sources of C3-R and C8-R highlight this situation as, "In my activity, I planned a trip to Virtual Museum of Muğla and activities that could be implemented there. While doing this, I preferred games for primary school students" and "I based my virtual museum tour (the Ephesus Virtual Museum) on instilling a love of museum, research, and observation in children."

Organization of Activities in the Context of Instructional Practices

The analysis performed with open coding on the text of the activity plans, the link regarding the museum where the activity would be conducted, worksheets (if any), and other annexes revealed the codes about instructional practices in the first stage. When the activity organizations were evaluated through the instructional exercises in the activity plans, it was seen that these practices could be grouped into three categories as before, during, and after the virtual museum tour. The relevant categories, codes, and reference representations for the instructional activities planned for the virtual museum tour are presented in Table 3.

Table 3. Educational Activities Planned Before the Virtual Museum Tour

Category	Code (f)	Activity form	Sample
Providing information about the museum	Providing a museum map (f = 15)	S2-A, S4-A, S5-A, S8-A, S12-A, S13-A, M2-A, M4-A, M7-A, M14-A, M16-A, C1-A, C3-A, C5-A, and C7-A	A virtual museum map is presented at the beginning of the activity and marking the relevant sections (S2-A). The map of the museum is introduced to the students through the Google Drive link shared by the teacher (M7-A).
	Providing a museum publicity brochure (f = 9)	S1-A, S3-A, S4-A, S5-A, S6-A, S7-A, S15-A, M8-A, and M14-A	I present the brochures I prepared online for the tour regarding the study of the fossil remains of extinct creatures (S6-A). A brochure about how to visit the museum (specific to each group section) is prepared with Canva and presented to the students (M14-A).
	Informing with a brief	M1-A, M3-A, M6-A, and M15-	Before entering the link of the museum, general information about the museum is presented, a

Category	Code (f)	Activity form	Sample
	introductory presentation (f = 3)	A	virtual reality tour is conducted, and the sections to be visited in the museum are introduced (M3-A).
	Watching an exhibition video (f = 3)	M5-A, M12-A, and M13-A	M13: Before the virtual trip, a short video of the museum exhibitions is shown to the students (M13-A).
Revealing expectations and prior knowledge	Understanding students' expectations for trip (f = 16)	S9-A, S10-A, S13-A, S15-A, M1-A, M6-A, M7-A, M9-A, M10-A, M11-A, M14-A, C1-A, C2- A, C4-A, C6-A, and C8-A	A form including questions such as, "Before the activity, what comes to your mind when you think of a science museum, and what are your expectations from the museum we will visit?" is applied (S9-A). A form is applied via Google Forms to ascertain the students' prior knowledge about the virtual museum to be visited (M6-A).
	Understanding students' content knowledge (f = 8)	S4-A, S5-A, S7-A, S8-A, S10-A, S11-A, S14-A, and S16-A	A worksheet is applied to determine the students' preliminary knowledge on the subject of "the Solar System" (S4-A).

Analyses reveal that before the virtual museum tour, activities were mainly used to provide introductory information to students about the museum and to determine the expectations and prior knowledge of the students before the trip. On the contrary, in some activity forms (e.g., S4-A and M7-A), more than one activity (e.g., providing students with a map for the museum and determining students' expectations) was aimed to be carried out before the virtual museum tour. The S4 reflective form reveals this situation as follows:

> While I was preparing this activity, I paid attention to what the students' prior knowledge could be and that the trip was related to the science lesson … I also toured the museum many times while preparing the activity … In some places, students could stray away from their learning goals. Therefore, I thought of giving the museum map and brochure to the students before starting the virtual tour. (S4-R)

When the frequencies of the codes related to the instructional practices are evaluated, the instructional practices aiming to benefit from the museum maps to provide information about the museum to the students and to reveal that the student expectations stand out as common in all three programs. With regard to this situation, S16 clarifies, "When I become a teacher, I will teach based on 5E (the 5E learning model). The beginning of 5E is to reveal the prior knowledge of the students and conduct the lesson accordingly" (S16-R), whereas S5 said,

> In the activity, I asked the students to observe the animal skeletons found in the first exhibition hall of the museum. I thought that the preliminary information I determined before the tour would enable me to decide how to guide the students while making these observations and what to focus more on. (S5-R)

The instructional practices planned for before the virtual museum tour reveal that the pre-service teachers also made effective use of Web 2.0 tools. As stated above, it was determined that besides the maps and brochures presented by the museums themselves, supportive tools such as Canva, Google Forms, and virtual reality were included in the instructional practices. From the classroom teaching program, S1 explained this situation as follows: "In this activity, I used various digital applications and platforms we learned in the lesson for the first time … I easily created the brochures I prepared with Canva … I preferred it because I could present it digitally to every student" (S1-R). In mathematics teaching program, C6 exemplified this by saying, "Since the education procedure is distance education, I thought that the expectation form should be prepared using Google Forms. This form also allowed me to instantly view and review student responses" (C6-R).

Analyses reveal that the instructional activities planned during the virtual museum tour also diversified within themselves. Categories, codes, and reference representations related to the instructional activities used during the virtual museum tour are presented in Table 4.

Table 4. Educational Activities Planned During the Virtual Museum Tour

Category	Code (f)	Activity form	Sample
Providing student interaction with virtual museum content	Using the Observation Form/Activity worksheet (f = 29)	S4-A, S6-A, S8-A, S10-A, S11-A, S12-A, S14-A, S15-A, S16-A, M1-A, M2-A, M3-A, M4- A, M5-A, M6-A, M7-A, M9-A, M10-A, M11-A, M13-A, M14-A, M15-A, M16-A, C1-A, C2-A, C4A, C5-A, C7-A, and C8-A	Using a form consisting of the section/name in which it is located, the remarkable part and the information given for each collection visited in the museum (S4-A). Using an observation form that associates information such as the type of the work with the geometric objects found in the work during the activity with the Google form (M2-A). Comparing the objects in the ethnography museum (below) with the objects in your daily life and writing and drawing their similarities or differences (M2-A).
	Presenting tasks (f = 16)	S1-A, S2-A, S5-A, S7-A, S8-A, S9-A, S10-A, S12-A, S13-A, S14-A, M6-A, M8-A, M10- A, M11-A, M12-A, and M16A	Finding the oldest dinosaur (Megalosaurus) fossil in the museum and providing information about it. Taking a screenshot (S1-A). Presenting images of certain works in the museum to students, asking them to find them and determine their properties (S2-A). The teacher gives a geometric shape to each group and asks the students in the groups to find that geometric shape in the virtual museum (M6-A).
	Drama (f = 3)	M7-A, C3-A, and C6-A	… They try to create the works they have chosen in the classroom by taking geometric shapes as the basis. With one of the drama methods, "Frozen Image," other students try to guess in this way (M7-A).
	Using estimation, observation, and explanation technique (f = 1)	S3-A	While visiting a certain part of the museum, predicting where the living things might have lived, observing the habitats of these creatures and comparing the predictions and observations (S3-A).

The analyses show that the instructional practices during the virtual museum tour are mainly planned to increase the interaction of students with the virtual museum environment, scientific information (information notes on the artifacts, signs, and explanations) about the digital objects, or artifacts. It was determined that such instructional practices are transferred to students through observation forms, activity worksheets, and challenging tasks. This situation was expressed in the reflection forms as follows:

> I tried to help the students' observation and data collection process by drawing attention to the artifacts and motifs in certain parts of the worksheets. This, I have provided convenience and guidance for the students who observe and record the data they find. (M11-R)

> The students are given riddles (worksheets) about the major exhibitions or the artifacts in the museum, and I aimed that the students find what was mentioned and look up the relevant exhibition. (C8-R)

Analyses reveal that the instructional practices used during the virtual museum tour are not limited to a single activity but can include more than one activity (e.g., presenting the students a task with a worksheet). M6 explains this situation as,

> My strategy for guiding the students as the teacher is the task of finding the determined data during the virtual tour … Three worksheets have been prepared for students to note the information they have acquired in the virtual tour where they will explore the subject by answering the questions about the tour. (M6-R)

During the virtual museum tour, it was observed that the Web 2.0 tool called Google Forms was used to a limited extent to guide students and make it easier for them to record the data that they collected. However, a considerable portion of the pre-service teachers prepared classic paper–pencil worksheets for the digital tour. This can be clearly understood from the expressions of C8-R, M6-R, and M11-R presented above.

Finally, analyses show that pre-service teachers demonstrate a deep understanding of instructional practice following the virtual museum tour. The categories, codes, and reference representations related to the instructional activities used after the virtual museum tour are presented in Table 5.

Table 5. Educational Activities Planned After the Virtual Museum Tour

Category	Code (f)	Activity form	Sample
Evaluation of the virtual museum	Virtual museum evaluation form (f = 18)	S4-A, S6-A, S7-A, S8-A, S9-A, S10-A, S14-A, S15-A, M1-A, M3-A, M6-A, M10-A, M12- A, M14-A, C1-A, C3-A, C5-A, and C8-A	At the end of the activity, students are asked to fill in the Google Form, which includes information such as the emotions of the museum tour caused for them and the most striking part of the museum (S4-A). Students who have completed their virtual museum tour are given the last questionnaire prepared by the teacher in the application called Google Form (M6-A). Students are presented with and asked to solve the puzzles about the museum prepared through

Category	Code (f)	Activity form	Sample
			"Crossword Labs" (C3-A).
	Presentation (f = 3)	S5-A, M6-A, and C3-A	(Students) Prepare a presentation with the application named Piktochart by summarizing the information about the museum (M6-A). Students are asked to prepare a presentation to advertise the museum (C3-A).
	Creating a video (f = 1)	M3-A	Students are asked to prepare an interactive video (with audio narration) for the museum using the Playposit Web 2.0 tool in a digital environment (M3-A).
Evaluation of content	Preparing a poster (f = 14)	S1-A, S3-A, S6-A, S10-A, S13-A, S16-A, M2-A, M7-A, M8-A, M9-A, M16-A, C2-A, C4-A, and C5-A	At the end of the activity, students prepare a poster containing the characteristics of the extinct animals in the museum (S1-A). Students are asked to prepare posters about the mathematics information the museum with Canva (M7-A). They are asked to prepare a poster about the geometric objects and shapes they find in the virtual museum (M9-A). A poster is prepared considering the information observed and acquired during the virtual tour (C2-A).
	Final evaluation form (f = 13)	S4-A, S10-A, S14-A, S15-A, S16-A, M1-A, M3-A, M5-A, M12-A, M13-A, M15-A, C6-A, and C7-A	An activity is conducted to identify the creatures that perform aerobic respiration with Learningapps (S10-A). The achievement test prepared after the virtual tour is applied to the students; hence, whether the tour reached its goals is determined (S15-A). The class is divided into groups and the groups are asked to create an infographic from the Padlet program using the data and information they have (M3-A).
	Group-class discussion (f = 6)	S2-A, S16-A, M4-A, M6-A, M9-A, and M11-A	After the trip, after the information of each group is presented, there is a discussion, and the most interesting optical tool students encountered during the tour is determined (S2-A). Students discuss among their peers about the information (characteristics, appearance, bone structure, and characteristics of the animals) that they have studied and acquired while touring the museum (S16-A). As a class, students discuss the findings that they have discovered and obtained as a result of the tour (M4-A). Students discuss and share the information that they have acquired through interviews on Zoom

Category	Code (f)	Activity form	Sample
			with their group mates (M6-A).
	Student drawings (f = 6)	S9-A, S10-A, S12-A, S15-A, C4-A, and C7-A	Based on the spacecraft seen in the Exploring Space section, what should be in a spacecraft is discussed. Students draw and design their dream spacecraft (S9-A). They draw a picture of what stuck with them from museum tour or an artifact that they liked (C4-A).
	Creating a story (f = 4)	S8-A, S10-A, S15-A, and C1-A	Students are asked about the technological tools that were there and why did they interest them? They create an audio story on this subject (S8-A). They are asked to write a story in the space below (on the worksheet) about the work they like most in the virtual museum (C1-A).
	Creating a design (f = 1)	S15-A	Students are asked to design a measurement tool for each group based on the designs in their virtual science center, using simple materials (S15-A).
	Creating a concept map (f = 1)	S11-A	After the virtual museum tour, students create a mind map about the celestial bodies in the Solar System (S11-A).
	Model building (f = 1)	S14-A	Finally, students create a Solar System model using the materials they find in their houses (play dough, paper, styrofoam, etc.) (S14-A).
	Reflective log (f = 1)	S10-A	Students create a reflective diary about the tour, including what was discovered, interesting, and acquired (S10-A).

After the virtual museum tour, focus was given to instructional practices regarding evaluations of the information collected about the virtual museum or the content within it. For the evaluations for the virtual museum, mainly evaluation forms were used. This situation was explained by the pre-service teachers as follows:

> I never thought I would take my students on a tour because I am a mathematics teacher, especially a virtual museum tour. I found this science museum as also suitable for my field, and I got the idea of conducting an out-of-school activity. As I was designing such an activity for the first time, I wanted feedback on how the virtual museum tour experience was for students (such as its shortcomings and suggestions). (M14-R)

> At the end of the activity, I thought of applying a form asking the students what their thoughts about the museum and museum tour were. According to the answers of the students, I would apply this virtual tour to other lessons in different museums. (S4-R)

For the content-oriented evaluations in the activity designs, the data collected in general terms, such as poster preparation aiming to share the observation results and experiences, story creation, student drawings, or final evaluation forms were used. Such general objectives were expressed by S13 as, "In the activity I prepared for the subject of biodiversity, I addressed the subject of endangered species … Virtual museums appeal to the sense of vision … I also wanted students to prepare a poster with visuals." (S13-R9)

In planning where evaluation forms were used, the aim was to gather information about whether the learning occurs in the targeted way with the virtual museum tour:

> The learning outcomes of my activity were related to the properties of the pyramids. With the form I used at the end of the lesson, I used the concepts acquired by the students with the virtual tour of the Egyptian pyramids to associate the basic elements of the pyramid in the curriculum … The important thing was to determine whether the lesson's goals were achieved or not … (M5-R)

The analyses also reveal that evaluation activities for both the virtual museum and the content were included in the activity forms. This situation is expressed by S10 as follows:

> Due to similar evaluation questions presented to the students before and after the virtual museum tour, I could evaluate the achievements of the students … With the museum form I created, I can understand what students feel and think about the museum that they toured (S10-R).

Discussion

Within the scope of this study, the activity plans created at the end of a program on how activities can be conducted in virtual museums in pre-service teacher education were examined. The descriptive analysis carried out in the first stage confirms the theoretical approaches put forward on the effects of virtual museums on education. The findings show that the activities were planned by pre-service classroom, primary school mathematics, and science teachers who chose a total of 26 different national and/or international virtual museums, regardless of the local language of the museums. Virtual museums have provided education with access to rare or geographically separated works of art and an unwalled, interactive understanding of museology (Kavanagh et al., 2017; Schweibenz, 2004). The findings reveal the fact that collection ideas and concepts shared through virtual museums can be used as tools for learning many subjects and concepts in a relational way with the curriculum. Analyses show that digital museum objects can be used for teaching many different subjects, from astronomy to geometric objects and from extinct animals to archeology and history, in the activities planned by the pre-service teachers. These findings support the current studies on the educational use of virtual museums (Angeloni et al., 2012; Kersten et al., 2017; Uztemur et al., 2019; Paquin, 2015). Another finding is that the collection ideas or themes used are shaped according to the specialty field of the pre-service teacher. For example, while different subjects such as extinct animals, optics, celestial bodies, and biodiversity are matched with virtual museum collections in the activity plans developed for the science course, there is a focus on general museum tours in the plans developed for classroom teaching. This situation reveals an understanding that disciplinary dynamics are included in the activity plans. In the literature, there are studies on the use of virtual museums in teaching cultural heritage, historical values, or social life in the history (Hsieh et al., 2010; Uztemur et al., 2019; Kersten, et al., 2017). The current research results also expand the literature on the basis of teaching different subjects and concepts in the context of science, mathematics, and classroom teaching.

Activity plans developed by the pre-service teachers from three different departments are curriculum materials specifically prepared for those fields, as expressed in the research method. In the analysis, it was seen that the instructional activities in all of the activity plans could be grouped into three categories. These were classified under the three themes of before, during, and after the virtual museum tour. Various instructional activities such as presenting a museum map or brochure to the students, using forms created with Web 2.0 tools (such as Google Forms and Kahoot) or PowerPoint presentations were included in the activity planning by the pre-service teachers before the virtual museum tour (see Figure 2). These findings indicate that pre-service teachers not only integrate virtual museums into their teaching processes as a standalone innovative technology but also demonstrate an integrated understanding with different Web 2.0 technologies on the basis of inquiry pedagogy. In this respect, this study supports the results of previous studies on the effective professional development of teachers (Minken et al., 2021; Morales et al., 2020).

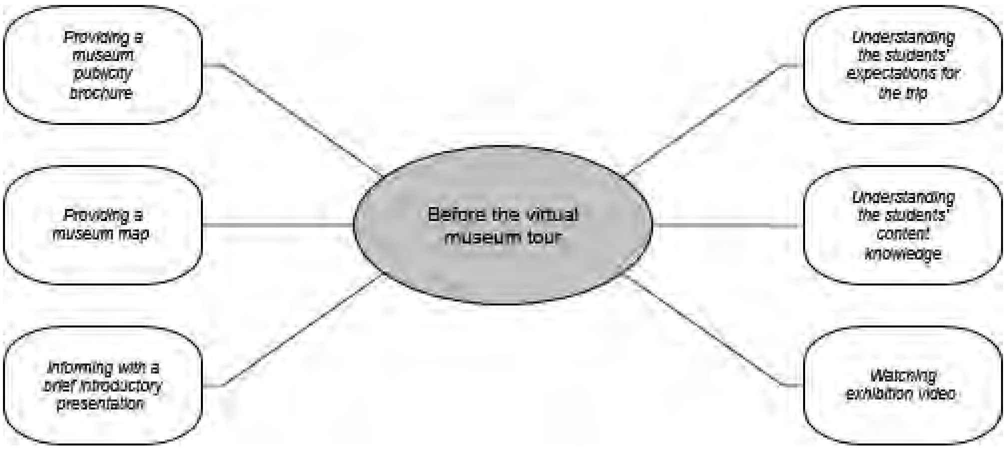


Figure 2. Educational Activities Planned Before the Virtual Museum Tour

Considering the collection ideas/concepts that they contain or their intended use, it was determined that these activities fall into two categories, namely, (i) providing information about the museum and (ii) revealing expectations and preliminary information. Schweibenz (2004) classifies the concept of museology in the virtual environment as a brochure museum, content museum, learning museum, and, finally, virtual museum. These environments represent museology understanding that moves from promotion to interaction with the information that they contain. The pre-service teachers' planning also includes similar understanding and instructional practices that go from informing in general to revealing expectations and prior knowledge for more interaction. Students' prior knowledge and experiences are precursors of their learning, and the teacher determining this knowledge is supportive in shaping student's self-learning (NRC, 2000a). In instructional practices focused on informing, the goal is to save time in general. As mentioned by Apostolellis and Bowman (2014), it is important that the limited time period of the museum tour is transferred to the reviews regarding the content. Simultaneously, providing virtual maps and compasses to increase the accessibility of the virtual museum environments are accepted as effective strategies to support learning (Angeloni et al., 2012). Thus, students are prevented from getting lost in different exhibition spaces or collections within the virtual museum.

During the virtual museum tour, some instructional practices that support the interaction of the students with the digital museum objects in the virtual museum were included in planning by the pre-service teachers. Structured work such as activity worksheets aiming to find answers to specific questions, open-ended or semi-structured observation forms, or completion tasks was prominent in the analysis (see Figure 3).

Figure 3. Educational Activities Planned During the Virtual Museum Tour

According to Paquin (2015), although digital learning objects in virtual museums are extremely useful for teaching, teachers prefer these objects to a limited extent. For this reason, such practices aimed at exploring museums more deeply and furthering interaction or building students' knowledge through evidence are considered important achievements for pre-service teachers. These findings also support research findings that emphasize the relationship between the learning process in museums and the constructivist theory (Haensly, 1999; Kavanagh et al., 2017; Styliani et al., 2009). In addition, the promotional museum materials and museum maps included in the activity plans were added to the designs as complementary to the activity worksheets and observation forms. During the activity, the student's goal was to quickly access a precise digital collection within the virtual museum or ascertain a general idea about the whole collection in the museum. Including such tools in planning was considered to facilitate the guidance process of the teacher. According to Vartiainen and Enkenberg (2013), scaffolding through the use of museum objects to cause inquiry or arrangements for usability is relevant. The maps and materials that the pre-service teachers used for activity planning were ready-made and taken from the systems of the virtual museums; this is an extremely expected behavior given the difficulty of material development. In the examinations, the fact that these tools were designed by the museum authorities for promotional reasons and to draw attention rather than guidance or educational purposes can be considered as an important limitation.

After the virtual museum tour, instructional activities aimed at sharing the acquired or produced information were included in the pre-service teachers' activity plans. These activities were mainly based on using Web 2.0 digital tools to include product-based work such as filling virtual museum evaluation form, group-class discussions, or video and photo catalog creation (see Figure 4).

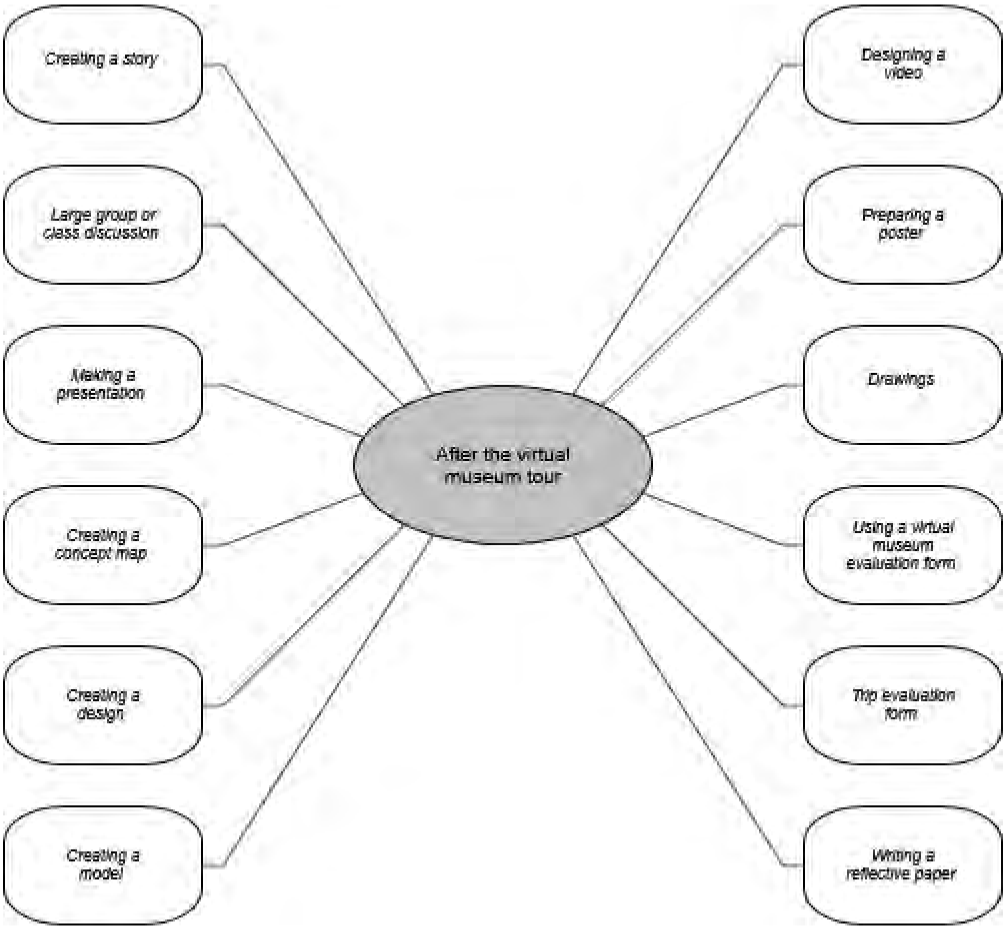


Figure 4. Educational Activities Planned After the Virtual Museum Tour

It can be said that the educational activities presented in Figure 4 serve to evaluate the virtual museum and the information obtained about the content. Evidence-based evaluations using such museum artifacts significantly support inquiry. NRC (2000b) claims that, for inquiry, the learner should include processes such as giving priority to the evidence, analyzing the evidence they have reached, developing explanations based on the evidence, associating the explanations with scientific knowledge, discussing the explanations, and justifying their ideas. Additionally, such practices can deliver a solution to Apostolellis and Bowman's (2014) critique about students who visit traditional museums, passively obtaining information from museum objects. This way, learning is not limited to the virtual museum tour process and can then be carried out in a collaborative environment based on the evidence obtained.

Conclusion

The results reveal the pre-service teachers' understanding of the use of digital artifacts in virtual museums through their activity plans. The results obtained show that the activity plans generally include virtual museum collections prepared in different geographies and different languages, as well as subject contents (e.g., creating a chart) and virtual museum collections (e.g., mathematics) within the pre-service teacher's field (e.g., mathematics teacher) in a relational understanding. Another result obtained through the activity plans is the organizational structure of the educational activities included in the planning by the pre-service teachers before, during, and after the virtual museum tour. Although the educational activities included in the planning for the three stages as a result of the analyses vary, they point to three main characteristics for teaching in virtual museums. These are guiding the virtual museum tour, supporting student engagement, and fostering learning outcomes. For example, the student discussions and introductory information planned before the museum tour and poster preparation and final evaluation forms planned for after the tour mainly aim to support the learning outcomes. Similarly, activities such as giving the student a map before the tour and the student studying the map, assigning the student with a challenging collection task to use the map during the tour, and then requesting a presentation consisting of screenshots showing that the task has been completed aim toward guiding the virtual museum tour.

Recommendations

This study reveals the ideas and understanding of pre-service teachers about the use of virtual museums in education through lesson plans. Based on this situation, the fact that the study was conducted with a certain number of pre-service teachers and the designed activities could not be carried out with students should be considered as the limitations of the study. The second phase of the study is to evaluate these practices put forward as a design in real learning environments and to bring pre-service teachers together with students through these practices. It is important for the instructional practices put forward in terms of the general structure to work in different contexts (such as in-service teacher working groups and distance or face-to-face education). On the contrary, the study findings offer practices that facilitate the inclusion of educational solutions in virtual museums for virtual museum platform developers and the expert teams planning virtual museum contents (brochures, posters, etc.).

Notes

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