International Journal of Engineering & Technology, 8 (1.4) (2019) 616-624

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The Study on the Possibility of Virtual Reality Museum Replacement in Reality Museum

YoungJe Yu[1], Woo Hyung June[2], Sun-Jeong Kim[3], Chang Geun Song[4]*

[1]*Hallym University*
[2] *Hallym University*
[3] *Hallym University*
[4] *Hallym University*
**Corresponding author E-mail: cgsong@hallym.ac.kr*

Abstract

In a great number of museums, there are curators in place to deliver information to the audience adjusting to the level of description depending on their age and/or level of intelligence. However, the reality is that there is not enough number of curator staffs. Due to such problem, it is practically impossible for every audience to be served by a curator. That is why audio guides and/or Near-Field Communication (NFC) tag systems have also taken place in museums.

In this study, the proponents have implemented a "Virtual Reality museum (VR museum)" by utilizing the virtual reality technology that has already been used widely in the fields of film, education, etc., nowadays. A virtual reality museum had been created similar to the Hallym University museum. The museum was created with the use of 3D MAX and Unity 3D. An NFC system has also been developed to describe the artifacts to the audience. The app has been implemented on mobile device such as tablet PC, or smartphone. A comparison was made with the real museum with curators, the real museum with NFC system and the VR Museum. There were 75 participants during the study. The research was carried out in the following order: First, an objective evaluation of the effect of the museum viewing was conducted on the visitors. Second, a subjective evaluation was also conducted about the overall feelings of the visitors on the museum viewing. Third, a comparative evaluation was performed on the usability among curator-assisted museum viewing, and museum viewing with NFC applications that provide help for the visitors of museums, and the virtual reality museum. Based on the three types of evaluation aforementioned, the study suggests that the curator's function can be replaced by NFC app or virtual museum. In the aspect of providing useful information about exhibits, there is no difference among three methods of curator, NFC and VR.

Keywords: *Curators, Education, Leap Motion, Museum, Oculus Rift, Virtual Reality*

1. Introduction

1.1. Research Background and Purpose

The visitors can tour the museums with the guidance of museum curators, escorting them according to their characteristics, such as age or education level. In this way, the curators can intrigue visitors and facilitate their understanding about exhibits. However, all the visitors cannot enjoy such benefits because of the lack of curators [10]. To address this issue, some alternative services have been developed, for example, audio guidance and smart phone application of Near-field communication (NFC) technology [7, 11, 12].

As smart phones have begun to be widely distributed, applications using the equipped NFC functions were popular; hence museums began to provide services in which they give out information through NFC technology [3, 6].

In 2016, the largest consumer electronics exhibition held in Las Vegas, USA, called CES, introduced the next generation virtual reality HMD products, such as Oculus Lift, Samsung Gear VR, HTC VIVE, etc.

Recently, virtual reality (VR) has been well appreciated by a number of fields other than computing field. This trend is becoming stronger as Oculus Rift and HTC VIVE have been commercialized, and VR has been applied to the movie, game, education, and medical simulation.

The use of VR made it possible to feel the things one usually could not experience easily in the reality as if they were "real". The virtual reality technology was being utilized in a wide variety of fields just by connecting the existing real contents to the virtual reality.

Another thing to notice is that the field of VR, which has already gone through great development and commercialization, is now being utilized in military and medical simulations. The absorbing power of VR is known to induce active participation as well as interest of the user.

In this study, a virtual museum has been created similar to one in reality, with the use of 3D MAX and Unity 3D. Using the VR museum, an experiment was conducted on the possibility of the new viewing method using VR replacing the existing methods of viewing the museum (curator's explanation, or the use of NFC app) and in providing explanations. The experiment confirmed the aforementioned possibility.

1.2. Research Methods and Hypotheses

VR has already been utilized in a wide variety of fields such as education, military training and so on.. In the same matter, on the premise that a VR museum could substitute a real museum, the proponents have come up with three hypotheses:

Hypothesis 1. The museum tour using virtual reality is easy to use compared to the typical way of the museum tour (using NFC app, curators).

Hypothesis 2. The museum tour using virtual reality technology provides the amount of information enough to replace the typical way of the museum tour.

Hypothesis 3. The subjective feelings of the museum viewers from the experiences of a VR museum and an existing museum would be the same.

A Virtual Reality (VR) Museum was specifically created to confirm the feasibility of the study and there were three groups created during the experiment according to the use of different viewing methods--the guidance of curator, smart phone application of NFC technology, and VR.

To test the three hypotheses, the experiment was conducted with 75 participants. The participants were divided into three groups of 25 participants and each group has experienced different types of the museum tour, such as the guidance of curator, smart phone application of NFC technology, and VR. After the experiment, all participants were asked to complete a subjective questionnaire, as well as an objective evaluation (test items).

As for the participants in the NFC and VR groups, they answered the questionnaire with additional queries about the usability. At the end of the experiment, a statistical analysis was also performed and based on the analysis results, the feasibility of the above three hypotheses have been verified, and then came up with the conclusion.

2. Related Works

There have been several studies using RFID equipment and virtual reality to describe the exhibit [1, 2, 3, 4, 5]. Çayırezme and etc. [1] argue that RFID technology can be applied in museum for inventories of artifacts, monitoring and tracking collections, and interactive museum displays. Ceipidor and etc. [7] had presented the design of a multimedia mobile guide for the visitors of the Wolfsoniana museum of Genoa. The visitor experience could be enhanced by making it more interactive and engaging during the visit, while the mobile application will be interacting with NFC and QR Code technologies to allow the visitor to easily access the additional contents and social functions with the visitor's smartphone. Studies have been conducted linking exhibits, places and themes through the Mobile Virtual Reality Museum [2].

Andrea and Pozzebon[4] created the Virtual Reality Museum using 360 degree photographs taken with two Go Pro Hero 3. The study focused on creating the Maria della Scala Museum of Virtual Reality. Webel and etc.[5] have created a system that will experience exhibits in a virtual environment, using equipment such as Oculus Rift, Microsoft Kinect, and Leap Motion.

Recently most of the virtual reality museum studies have been content-based using 360 degree video. In fact, most virtual reality museums in the present were content based on 360 degree images [4]. The contents can be viewed with a 360 degree by mouse rotation on a webpage. However, these contents were not three-dimensional and the user could not interact with the exhibits because they were made based on photographs. This study used 3D MAX to create an environment that is similar to a real museum that compensates for the shortcomings of the 360 degree images. In addition, exhibits within the museum could be directly controlled by allowing interaction between the user and the virtual reality museum.

There have been many studies on virtual museums. Most of them have made existing museums into virtual museums using ICT technology including VR or AR [19, 20, 21, 22, 23].

Sylaiou and etc. [23] implemented the virtual museum based on an existing galley in the Victoria and Albert Museum, London, UK. It is of interest to determine whether a high level of presence results in enhancement enjoyment. They found that enjoyment and both AR objects' presence and VR presence were found to be positively correlated.

Briella, Luther and Sacher [24] describes ongoing work and further enhancements of the Replicave2 framework, which supports museum designers creating virtual museum exhibitions by reusing 3D models and dynamically generated content.

Further relevant work continuously appears in Museums and the Web [32], the largest on-line international conference devoted to the exploration of art, science and natural and cultural heritage. However research on the possibility that a virtual museum could supplement the scare number of curators was to hard to find.

3. Experiment Preparation and Program

The museum in Hallym University was chosen for the experiment since the museum is so small that the counterpart of the real museum, called VR museum, can easily be implemented, while the experiment environment can easily be controlled. Before carrying out the experiment, the artifacts to be explained about were identified first. The artifacts were selected by the curator of the museum. There were five artifacts chosen; Gong-ryeol Earthenware, Polished Earthenware, Red Polished Earthenware, Bronze Daggar, and Patternless Earthenware.

From the museum curator, the necessary information has been acquired about the artifacts to be used in the experiment. The data received were the videos related to the artifacts, the images of the six different sides of each artifact, and the script which the curator used for the explanation to the audience.

The NFC app experiment in the museum required a WIFI environment so the WIFI status of the museum had to be checked first. The museum was equipped with its own WIFI system, but the signal was not strong enough, which could possibly cause problems in the communication between the NFC app and the server. To complement the weak WIFI signal, an additional router was installed. By checking on the signal intensity of the additional WIFI router, the proponents made sure that no problem would occur in the streaming of the contents using the NFC app.

For the VR Museum experiment, a private space has been prepared because outer distractions may affect the experiment as it provides sound and video information. All of the possible obstacles for the safety of the participants were removed as they participated in the experiment wearing HMD.

3.1. VR Museum

Virtual reality system was produced using Unity 3D 5.3.2f1 version [17] with Windows 7(64bit) computer (Intel i7-2600 processor, 8GB Ram, GeForce GTX 560ti SLI).

Fig. 1: VR Museum implemented with Unity 3D

The museum in reality, which served as the model of the VR Museum is the one in Hallym University. Oculus Rift DK2 was used for the head-mounted display [16]. Oculus Rift DK2 is a device which enables the viewer to see all the content in 360 degrees, rather than just in one direction. It is similar to the products such as VIVE from HTC, or Sony VR. Oculus Rift DK2 is equipped with the viewing angle of 100 degrees, and the resolution of 960x1080. With the use of gyroscope, accelerometer, magnetometer sensors, the update rate would amount to 60 Hz and the video plays smoothly when viewing the scene. Navigating between exhibits, video and audio contents were available within the virtual reality system. Leap Motion [15] was attached in the front of Oculus Rift DK2. Refer to Figure 2. Leap Motion is a sensor device that recognizes hand motion as input without any hand contact or touching. Leap motion recognizes the motions of hand and fingers within the 3D space of 8 cubic feet (30cm diameter). It can differentiate the left and right hand, and notice the finger gestures.

The exhibits for the VR museum has been created with 3D MAX2010 [14]. For the viewers to keep their concentration on the artifacts, the movement within the VR Museum has been limited to that between the four artifacts to be explained about. This was because the viewers should be concentrated on the artifacts, just as the group would concentrate on curator's explanation while viewing the museum.

Fig. 2: Leap Motion attached to Oculus Rift 2

Participants were able to move towards the exhibits by using left and right hand motion recognition into the leap motion (left: move to previous exhibit, right: move to next exhibit). Once participants are placed in front of exhibit, two options would be given—to choose either video or audio contents as Figure 3.

For the contents selection method, the Gaze method [8] has been used. In Gaze method, one assumes that there was an imaginary dot on the centre of one's direction. Using the imaginary dot, one would select the menu with the movement of one's head or one's gaze, and if the gaze has been made for longer than 3 seconds, it would automatically move on to the following menu.

In the video contents, the videos related to the artifacts would be played. As for the audio contents, the voice for the explanation of the artifacts, as well as the target objects with 6-sided pictures, would be provided. The voice has been recorded using the letter-reading function of Google Translator.

Fig.3: Content selection screen

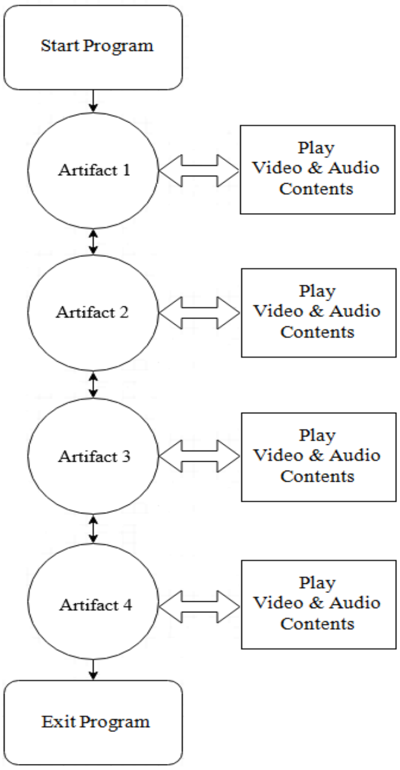

Fig. 4: The process of using the VR Museum

As the VR Museum Program starts, it would view the starting location of the program. From the starting location, one can move between artifacts 1~4. One can also move forwards and backwards if needed. In other words, during the view of Artifact 2, one can not only go forward to Artifact 3, but also go back to Artifact 1. After the user goes to the front of each artifact, he/she can select the video/audio contents and do the viewing (see the Figure 4).

When manipulating the video and audio contents, “pinch” motion was used. The pinch motion used in the manipulation of the contents requires precise motions, due to the recognition rate of Leap Motion. Figure 6 shows a precise pinch motion. When the user uses the left hand to do the pinch motion, the contents replay from the start. When doing the pinch motion with the right hand, the content would pause. Another pinch motion with the right hand would resume the contents. The pinch motion using both hands would lead to the main screen (museum screen), from which the user could choose the video/audio contents. Table 1 shows the methods of manipulation of the contents in the VR Museum.

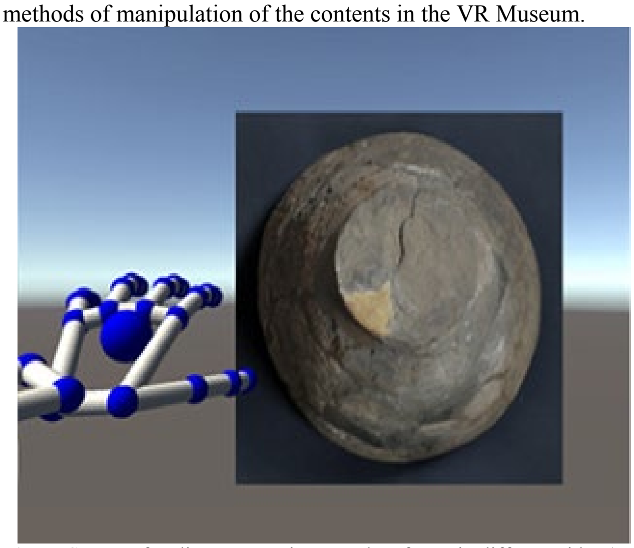

Fig. 5: Screen of audio content-Pictures taken from six different sides (top, down, left, right, front, back) have been applied. Rotating are done through swiping motion

During audio explanation of the artifacts, the user can rotate the objects. A transparent hexahedron surrounds the object like a bounding box. On the six sides of the hexahedron were the pictures of the six sides of the object. Through this process, the user can observe in detail the underside of the artifacts, as well as the inner parts of earthenwares, which can hardly happen in the viewing of real museums.

To manipulate the bounding box with the pictures of the artifacts, the user can use the “swipe” motion. To do the swipe motion, just as one should touch the smart phone screen, and drag into a line, one should locate his/her palm on the centre of the screen and swipe it to all the four directions. Table 2 shows the functions of the swipe motions.

Fig. 6: Precise pinch motion-For higher recognition rate, a precise pinch motion is critical. Precise pinch motion requires the point of index figure and thumb touching as other three figures to be straightened

Table 1: VR Contents Manipulations-The Pinch Movement used in both video and audio contents

Motion	Result
Left-hand pinch motion	Video/Audio Replay
Right-hand pinch motion	Video/Audio Pause
Both-hands pinch motion	Go to the Main Screen

Table 2: Pictures Manipulation of the VR Museum

Motion	Result
Left hand (left, right swipe motion)	A hexahedron with pictures of artifacts is rotated in the x-axis(left, right) direction
Right hand (up, down swipe motion)	A hexahedron with pictures of artifacts is rotated in the y-axis(up, down) direction

3.2. NFC application

NFC system are made with the Android Studio (compile sdk version 11, Build Tools Version “24.0.1). NFC system was composed with an Android app that displays artifact’s information and streaming server that transmits information. The streaming server were used with a Windows Server 2008 64bit computer (intel Xeon processor, 4GB RAM). Android app has been installed onto Google Nexus 7 and was used for the study.

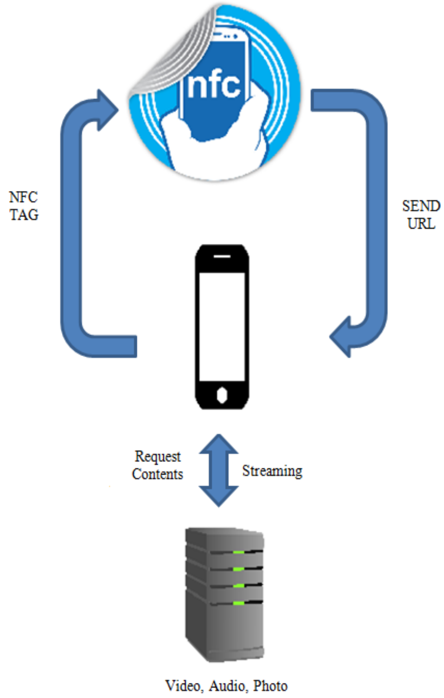

Fig. 7: Diagram of the NFC system-when an NFC equipped device is tagged to the NFC tag, prepared image, video and audio contents for the applying artifact are requested and then shown in the app

The main function of the NFC system, as one can see in Figure 7, is the streaming of the information related to the artifacts. For the streaming, a streaming server was configured using HLS (HTTP Live Streaming) method.

The Android app receives the video/audio/photo information from the streaming server for the output on the screen. When a participant starts the app, the main screen appears. If an NFC tag is tagged at the main screen, the assigned contents would be delivered and displayed from the server to be streamed, as one can see in Figure 8. The contents consist of three types: video, audio, and image. The contents to be streamed can be changed at the Option screen. Video content was the default.

Figure 8 shows the Start screen of NFC app. In case of NFC app, for the users' convenience, video and/or audio contents would be replayed if the device was tagged to an NFC tag at the main screen.

Fig. 8: NFC app main screen

3.3. Questionnaire

To evaluate the experiment environment of VR museum, NFC app, and curator, three types of questionnaire were given. First, the objective questionnaire has been prepared to see the educational effect of each experiment. It is a test which consists of 8 question items about the 4 artifacts. Every participant is required to take the test after finishing museum viewing. Each question item is a multiple choice item, consisting of 4 options. The expert(s) prepared the question items taking the participants into consideration, who were college students. Table 4 shows the objective questionnaire.

Second, a subjective questionnaire has been prepared to see the participants' subjective feelings after the experiment. The subjective evaluation consisted of 6 question items. It is created to be evaluated by using 5 Likert Scale(see the Table 3).

Finally for the usability evaluation for the participants in both NFC and VR groups, the proponents used the questions of System Usability Scale(SUS) by John Brooke[13].

Table 3: Subjective Evaluation Questionnaire

Questions	1	2	3	4	5
1. After the explanations on the artifacts, it became easier for me to understand.					
2. To understand the artifacts, I was in need of additional media information(video, audio, photos, etc.).					
3. I think the memory of the artifacts would last longer after the museum viewing.					
4. I am willing to visit the museum again if provided with the same services.					
5. After the museum viewing, I think I would be able to explain others about the artifacts by myself.					
6. It is convenient to look at or listen to the explanations of the artifacts.					

Table 4: Objective Evaluation Questionnaire

Questions
1. Which of the following belongs to the Bronze Age? a. Jeul-mun Earthenware b. Hardened Patternless Earthenware c. Polished Earthenware d. White Porcelain
2. Which is correct among the explanations about Red Polished Earthenware? a. Polished Earthenware refers to the earthenware created by applying some iron-oxide liquid on its surface, rubbed with a smooth tool, and burnt in the kiln. b. Polished Earthenware is of the Iron Age, so it was made tougher than the earthenware of the Bronze Age. c. It is the one carved in circle patterns under its lip part. d. With its comb pattern on its surface, it is estimated to belong to the Neolithic Age.
3. Which is the type of the bronze daggers of the Bronze Age that are called “Korean-style bronze dagger” as they are excavated near the south of Cheong-cheon River in the Korean peninsula, have an edge on the center back part, and becomes narrower to the end? a. Liaoning-type Bronze Dagger b. Wide-type Bronze Dagger c. Taochijian d. Korean-type Bronze Dagger
4. What is the name of the drag boxes, which serve as the evidence of bronze-dagger making in the Korean peninsula as they are excavated in Chobu-li in Yong-in City, or Yeong-ahm in Jeon-nam Province? a. Pi-hom b. Cast c. Deung-dae d. Eo-im
5. Which explanation is correct about bronze daggers? a. Taochijian is an assemble-type sword which can be used by putting together the handle and its adornments. b. Korean-type Dagger is an integrated-type sword which has the handle altogether. c. Korean-type Bronze Dagger and Liaoning-type Bronze Dagger are presumed to belong to the same system, as their structures are similar to one another. d. Korean-type Bronze Dagger and Tochijian are presumed to belong to the same system, as their structures are similar to one another.
6. Which is incorrect about Gong-ryeol Earthenware? a. It appears from the early period of the Bronze Age, and it was first manufactured in the North East part of the Korean peninsula, then spreaded toward the South. b. It is the one carved in circle patterns under the its lip part. c. The pattern of the earthenware was all carved from the inside towards the outer side. d. Along with the hole-pattern decorations, it is adorned with lip-part decorations, as well as comb-pattern decorations.
7. Among the following, which is the earthenware from the Iron Age, with its name indicating the toughness compared to the Bronze Age? a. Jeul-mun Earthenware b. Polished Earthenware c. Gong-ryeol Earthenware d. Hardened Patternless Earthenware
8. Which is incorrect about Hardened Patternless Earthenware? a. Unlike the earthenware of the Bronze Age, they were created in vaious forms, including arch, wide, or deep. b. They were excavated in the remains in the Center part of the Korean peninsula, such as Jungdo in Chuncheon City, Igok-li in Gapyeong City, Majang-li, Pungnap-dong in Seoul City, and Gapyeong-li in Yangyang City, etc. c. It is related to the starting period of the Iron Age. d. Apart from the tradition of patternless earthenware of the Bronze Age, it individually created itself and developed into Tanalmun Eathenware.

4. Three Types of experiments

75 participants gathered for the experiment. All participants were students of Hallym University as most of visitors to the museum are Hallym university students.

4.1. Experimental Procedure

All participants were instructed about the study prior to the experiment. In the case of NFC experiment, participants were informed about the NFC app instruction, NFC tagging method, and option settings In the case of VR experiment, the participants were taught how to manipulate the VR gear. For the fairness of the experiment, participants were given 30 minutes to explore considering that curator’s explanation period is 30 minutes. After VR museum tour, participants were given a simple test to assess how accurately the information was delivered to the participants. Also, a subjective survey was given in order to collect participants’ experience towards the system. Certain amount of participants’ fee was provided for the participants.

4.2. Curator Experiment

Fig. 9: Curator Group in the Experiment

For an efficient experiment, 25 participants were divided into four groups. Each group, arranged with 5-7 people, was instructed to tour the museum with the guidance of a museum curator. Script for the tour was pre-arranged and equally presented for each group. Also, for the fairness of the experiment, the four groups got the explanations from the same curator. After the tour, a quiz called objective survey about the exhibition and a subjective survey was conducted. Figure 9 shows the curator group. And unlike virtual reality or NFC experiments, participants were not asked about usability questionnaire.

4.3. NFC Application Experiment

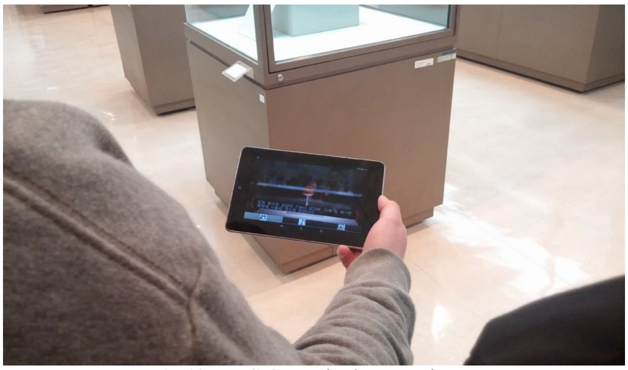

Fig.10: NFC Group in the Experiment

Same with the Curator experiment, NFC app experiment was also conducted inside the museum. 4 tablets equipped with the NFC app, hence 1~4 participants of NFC app group were together for a single turn. Before the experiment, the participants were briefly informed about how to use the NFC tagging app. There were 3 functions in NFC app; the first was to see the photos of the artifacts taken from various sides, the second was to watch the historical explanation or additional video about the artifacts, and the third was where the user can listen to the same content as the curator's explanations. For all participants in NFC app group, the use of the audio explanation function was a necessity, and the use of all functions, including photos and related videos, was recommended. For the smooth operation, the experimenters were situated inside the museum, while the participants viewed the artifacts using NFC app.

Google Nexus 7 tablet with related apps installed was used for the NFC experiment. Participants were able to access information about the exhibit such as video clip, audio and full image, by tagging the NFC sticker, which was placed in front of the window glass of each exhibit. After the NFC experiment, a simple quiz, called objective questionnaire about the exhibition and subjective survey was conducted. In addition, participants were asked to fill out a survey about the usability of the system. Figure 10 shows how users use NFC to obtain museum artifact information. The NFC app used in this experiment is the same system used in the previous study [23].

4.4. Virtual Reality Museum Experiment

Fig. 11: VR Museum Group in the Experiment

The VR Museum experiment was conducted in a calm, isolated, and individual space. Before the experiment, a training session was provided for the participants to get used to the manipulation of the VR system. In case a participant feels lack of understanding of the manipulation of VR Museum through one training session, the experimenter could repeat the training as needed. Each training session lasted for about 10 minutes. After the training session, a 5-10 minute recess was provided. This was because the user might feel dizzy, which was one of the noticeable traits in a VR system. After the recess, 30 minutes of VR Museum experiment was conducted. The participants were informed that they could immediately halt to the experiment in case they feel dizzy or anything unexpected took place.

The participants experienced the VR Museum along the pre-designed (focused on the four artifacts) route. During the experiment, if a participant would ask a question about the manipulation of the VR environment, the experimenter, having kept his place in the museum, would address it. The VR Museum experiment, just as the NFC app experiment, asked the participants to complete an objective and subjective questionnaires and also an additional questionnaire about the usability. Figure 11 shows a user viewing a museum's artifact through a virtual reality environment.

5. Result

The comparison of the three groups, VR, NFC, and Curator, wherein Curator is real museum, are summarized in Table 5 and 6.

Table 5: Objective evaluation ANOVA result

	VR	NFC	Curator	Total	P	F
Number (N)	25	25	25	75	0.908	0.096
Mean (M)	4.20	4.40	4.36	4.32		
Standard Deviation (SD)	1.87	1.58	1.65	1.68		

Table 6: Subjective evaluation ANOVA result

	VR	NFC	Curator	Total	P	F
Number (N)	25	252	25	75	0.175	1.789
Mean (M)	19.68	19.12	20.92	19.90		
Standard Deviation (SD)	3.52	3.24	3.55	3.48		

Table 7: Usability evaluation t-test result

	N	Mean	SD	P	T
VR	25	33.56	6.42	0.11	1.63
NFC	25	36.24	5.14		

5.1. Objective Evaluation Result

For the objective evaluation of the three different experiments, 8 questions about the artifacts the participants viewed were made. The 8 evaluation items were created by an expert of the artifacts. Using these questions, the proponents evaluated how much knowledge the participants acquired. The 8 items were all multiple choice questions, similar to exam questions, wherein a higher score meant more knowledge gained. Each item was calculated as 1 if correct, and 0 if incorrect, and then the result is total score to be used as the index for the objective evaluation. This method is commonly used in statistics, in which the number of correct items was put into use. To avoid subjective and emotional intervention, a different expert for creating the evaluation questions was hired, rather than the curator who provided the explanations about the artifacts.

To check if there were any differences in objective evaluation between the three groups (Curator, NFC and VR), One-way ANOVA was used for the score difference. As Table 5 shows, there was no significant difference in the objective evaluation scores of all three experiences (Table 5, Figure 12, P = 0.908, F = 0.096).

This result indicates that the three methods (Curator, NFC and VR) do not cause much difference in the acquisition of knowledge.

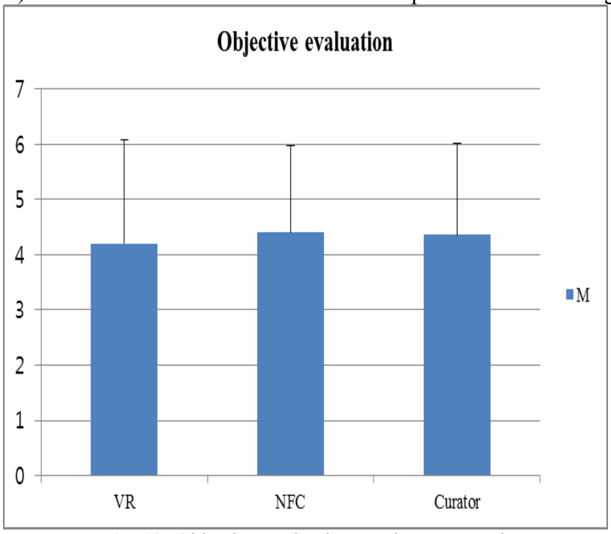

Fig. 12: Objective evaluation result mean graph

5.2. Subjective Evaluation Result

After the experiment, a subjective survey was conducted about the tour method. Survey consisted of six questions and each question was assessed with a five-level Likert scale. One way ANOVA was conducted to determine whether there were differences in subjective assessment of the three experimental methods (Table 6, Figure 13. F = 1.789, P = 0.175). As shown in Table 6, the differences in subjective assessment for the three experimental methods were not statistically significant. Therefore, the user's subjective evaluations of Curator, NFC, and VR were similar.

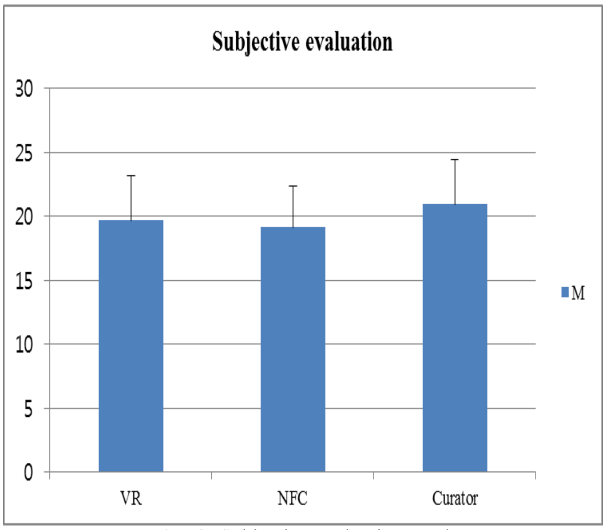

Fig.13: Subjective evaluation result

5.3. Usability Evaluation Result

For the usability evaluation for the participants in both NFC and VR groups, the questions of System Usability Scale(SUS) by John Brooke[13] are used.

The usability was evaluated using 10 evaluation items [5] of System Usability Scale(SUS) by John Brooke.[13] Among the 10 items, 5 shows higher usability when the value goes up, while the opposite was true for the other 5. Therefore, for the items that showed higher usability in lower values, they were converted to indicate higher usability in higher values, and by using those converted values, the proponents referred the sum of the 10 item scores as the usability. In that case, the Cronbach for this sum was 0.824, indicating a high conformity.

As shown in Table 7, the usability of NFC and VR was 36.24 for NFC and 33.56 for VR, indicating a higher score in NFC. A t-test was conducted on the difference of the scores to see if the usability of the NFC app experiment environment and the VR museum experiment environment were different. The results revealed that the usability of NFC and VR showed no statistically significant difference (P=0.11). Therefore, it can be said that there was no significant difference in the usability of these two methods.

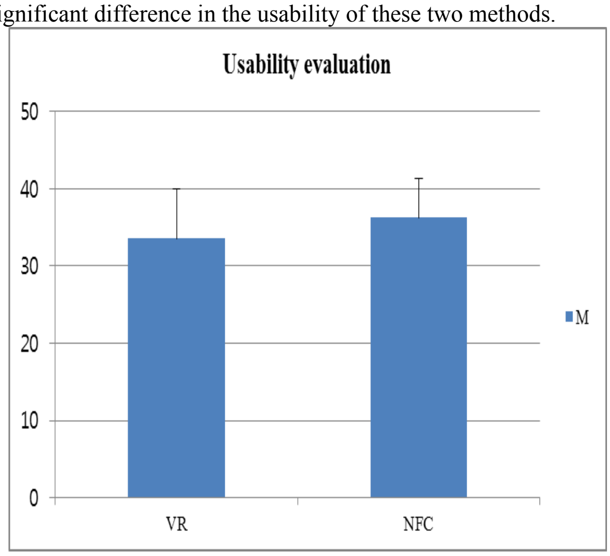

Fig.14: Usability evaluation result

6. Discussion

In the study, three hypotheses were formulated: 1) The museum tour using virtual reality is easy to use compared to the existing way of the museum tour (NFC app, curators); 2) The museum tour using virtual reality provides the amount of information enough to replace the existing way of the museum tour; and 3) the subjective feelings that viewers have in both VR museum and reality museum would be the same. To prove these three hypotheses, three types of experiment environments (VR, NFC, and Curator) were conducted.

In the evaluation of objective question items, the average scores were similar in all three experimental environments - VR, NFC, and Curator. Also, the ANOVA analysis does not show any significant difference. This was the result that supports the second hypothesis.

According to subjective evaluation results, the average scores of VR, NFC, and Curator groups were almost the same. Also, ANOVA analysis does not show any significant difference. This was the result that supports the third hypothesis.

The results of the usability evaluation show that the average scores of the VR and NFC experimental environments were similar. In addition, as the two experimental conditions were analyzed using t-test, which is one of the statistical analysis methods, there is no significant difference in the results. This supports the first hypothesis.

Since the VR museum experiment provided an ample amount of training sessions, there was no problem in carrying out the experiments. Most of the participants in the VR museum experiments were immersed in the experiment, enjoying the real-like scene of the museum implemented in the VR environment. Experience of VR environment may cause dizziness, which could be a disturbing factor in experimental features that require concentration. Hence, additional questions were included about whether the participants in the VR Museum had undesirable experience such as dizziness. None of the 25 participants replied that they felt dizzy. It can be seen that the experiments in the virtual reality environment were performed normally and smoothly without interference.

In the NFC experiments, no participant had troubled with the operation of the NFC system because the content was automatically executed when tagging the tablet in the NFC tag of the artifact. Also, as the experimenter watched the participants using the NFC app. The participants were encouraged to use all the functions of the NFC app. This means that the participants of the experiment in the NFC environment have faithfully carried out the experiment and the experiment has proceeded normally and smoothly.

The Curator experiment was carried out by setting the number of group members in advanced according to the curator's guidance. Since there were less than 7 students per group, the participants showed their concentration towards the curator. After the experiment in the Curator environment, participants were asked whether the curator's explanation was cut off in any way. All the participants answered that the explanation of the curator was well communicated. It can be said that the Curator environment experiment normally proceeded without interference.

7. Conclusion

In this study, the proponents have researched whether the VR Museum system can replace the curator's exhibition method, or an NFC app which helps visitors to view the museum. A museum viewing system has been developed through NFC app, which is one of the existing museum viewing methods. The developed NFC app was built with the emphasis on the convenience of the user, and the content was executed immediately when the device is tagged to the NFC tag.

In addition, a virtual museum very similar to the existing one was created. The virtual museum was a 3D space created for the study, and not by the images through a 360-degree shooting. The viewing scenarios and virtual museum manipulation methods for viewing virtual museums were all defined.

Three surveys were conducted to compare the effects of the existing museum viewing methods and the VR Museum. The surveys were three types: subjective, objective, and usability evaluations. The average scores of the three evaluations were almost similar. Subjective and objective evaluations were analyzed using ANOVA. Statistical analysis showed that all three methods were similar to one another. Usability evaluation was evaluated only for NFC and VR museums because it was related to the system use. The average score of usability ratings was also similar, with a slightly higher score in the NFC group. Usability evaluation was analyzed by t-test among statistical analysis methods, and the statistical analysis showed no significant difference in usability between NFC and VR museum. These results proved the three hypotheses initially proposed.

However, in the case of NFC or VR, there may be a difference in the quality of the information obtained by the user, depending on the information providing method and the quality of the information. Therefore, it can be seen from the objective evaluation that a well-implemented VR system can achieve effects that are not different from those described directly by an expert curator.

Future studies shall focus on two aspects. Most of the artifacts in this paper consisted of several earthenwares. Because of their nature, the earthenware was already in a state of having been broken and needs much attention and care. It was also impossible to exhibit earthenware directly without a cradle. As such, there were many limitations in scanning or modelling the artifacts. If the future studies can be carried out with artifacts such as bronze mirrors or bells that do not have a problem of being crushed, scanning artifacts and making them in 3D will be much simpler and implemented in a higher level. If future researchers make VR Museums using such artifacts, higher scores could be expected than actual museums in subjective evaluation.

Secondly, the manipulation method used in the virtual museum was 3D input using Leap Motion device. It took a few trainings for the users to familiarize themselves with Leap Motions, because it was a non-popular 3D input device. The use of conventional input device such as a keyboard, a mouse or a game controller would make it easy to operate, which would also lead to a higher score than NFC app in usability.

Acknowledgement

This research was supported by a Basic Science Research Program through the National Research Korea (NRF) funded by the Ministry of Education (NRF2017R1D1A1B03035576) and supported by Hallym University Research Fund, 2015 (HRF-2015-03-017).

Reference

[1] Nurdan Atalan Cayirresmez, Hakan Melih Aygun, Levent Boz, “Suggestion of RFID technology for tracking museum objects in Turkey”, Digital Heritage International Congress (DigitalHeritage), (2013), pp: 315-318, http://dx.doi.org/ 10.1109/DigitalHeritage.2013.6744770

[2] Holger Graf, Jens Keil, Alfonsina Pagano, Sofia Pescarin, “A Contextualized Educational Museum Experience Connecting Objects,

Places and Themes through mobile Virtual Museums”, Digital Heritage, (2015), pp:337-340, http://dx.doi.org/10.1109/DigitalHeritage.2015.7413896

[3] Athanasios Fevgas, Nikolaos Fraggogiannis, Panagiota Tsompanopoulou, and Panayiotis Bozanis, “The iMuse Virtual Museum: towards a cultural education platform”, The 5th International Conference on Information, Intelligence, Systems and Applications, (2014), pp:171-175, http://dx.doi.org/10.1109/IISA.2014.6878817

[4] Andrea Fineschi, Alessandro Pozzebon, “A 3D virtual tour of the Santa Maria della Scala Museum Complex in Siena, Italy, based on the use of Oculus Rift HMD”, International Conference on 3D Imaging (IC3D), (2015), http://dx.doi.org/10.1109/IC3D.2015.7391825

[5] Sabine Webel, Manuel Olbrich, Tobias Franke, Jens Keil, “Immersive experience of current and ancient reconstructed cultural attractions” Digital Heritage International Congress (Digital Heritage), (2013), pp:395-398, http://dx.doi.org/10.1109/DigitalHeritage.2013.6743766

[6] Yaw Anokwa, Gaetano Borriello, Trevor Pering, Roy Want, “A User Interaction Model for NFC Enabled Application. Pervasive Computing and Communications”, IEEE International Conference on Pervasive Computing and Communications Workshops, (2007), pp:357-361, http://dx.doi.org/ 10.1109/PERCOMW.2007.18

[7] U. Biader Ceipidor, C. M. Medaglia, V. Volpi, A. Moroni, S. Sposato, M. Carboni, A. Caridi, “NFC technology applied to touristic-cultural field: a case study on an Italian museum”, 5th International Workshop on Near Field Communication (NFC), (2013), http://dx.doi.org/ 10.1109/NFC.2013.6482445

[8] Rowel Atienza, Ryan Blonna, Maria Isabel Saludares, Joel Casimiro, Vivencio Fuentes, “Interaction Techniques Using Head Gaze for Virtual Reality”, IEEE Region 10 Symposium (TENSYMP), (2016), pp:110-114, http://dx.doi.org/ 10.1109/TENCONSpring.2016.7519387

[9] YoungJe Yu, Woo Hyung June, Sun-Jeong Kim, Chang Geun Song, “Educational Effectiveness of Virtual Museum”, International Journal of Multimedia and Ubiquitous Engineering, Vol. 13, No2, (2018), pp:21-26, http://dx.doi.org/10.21742/ijmue.2018.13.2.04

[10] Yang Ji-Yeon, Yi Byung-Jun, “Education and Training Needs of Museum Education Professionals”, KOREA ART EDUCATION ASSOCIATION,Vol.21, No.3, (2007), pp:289-325

[11] Cho Mi-young and Kim Ki-cheon, “A Study on NFC Market Status and Activation Plan” The Journal of The Korean Institute of Communication Sciences, Vol29. No.6, (2012), pp:55-65

[12] Sunhee Bhang, Hyojin Lee, Hyojung Jung, “Design of Mobile Learning Application at the Museum for Experiential Learning”, Korean Journal of the Learning Sciences, Vol.6, No.1, (2012), pp.45-64

[13] John Brooke, “SUS - A quick and dirty usability scale”, Usability evaluation is industry 189, (1996), pp:4-7,

[14] Richard H. Y. So, Andy Ho, W.T. Lo, “A Metric to Quantify Virtual Scene Movement for the study of Cybersickness: Definition, Implementation, and Verification, “ Presence, Vol. 10, No. 2, pp193-215, April 2001.

[15] Jason Moss, “Characteristics of Head Mounted Displays and their effect on simulator sickness, “ All Dissertations, Paper 214, 2008. .

[16] Huong Q.Dinh, Neff Walker, Chang Song, Akira Kobayashi and Larry F.Hodges,” Evaluating the Importance of Multi-sensory Input on Memory and the Sense of Presence in Virtual Environments, Proc. of Symposium on VR conference pp. 222~228, 1999. IEEE

[17] No Jun Kwak, Dong Hyun Jeong, Chang Geun Song, "Developing an Efficient Technique of Selection and Manipulation in Immersive V.E.", Procedding of the ACM Symposium on VRST 2000, p142-p146, 2000. ACM

[18] Dong Hyun Jeong, Young Hye Jeon, Jeom Keun Kim, Songyong Sim, Chang Geun Song, " Forced-based Velocity Control Technique in Immersive V.E., GRAPHITE 2004, p237-241, 2004. ACM

[19] Julian Llanos, " Is it Possible a Virtual-Eco-Museum?", Digital Heritage, Vol. 2, pp679-682, 2015.

[20] Simona Giglio, Lorella Gabriele, Assunta Tavernise, Pietro Pantano, Eleonora Bilotta, Francesca Bertacchini, "Virtual museums and Calabrian Cultural Heritage: projects and challenges", Digital Heritage, Vol. 2, pp703-708, 2015.

[21] Eva Pietroni, Massimiliano Forlani, Claudio Rufa, "Livia's Villa Reloaded: An Example of Re-use and Update of a Pre-existing Virtual Museum, Following a Novel Approach in Storytelling Inside Virtual Reality Environments," Digital Heritage, Vol. 2, 2015

[22] Arief Syaichu Rohman, Ary Setijadi Prihatmanto, Ratri Dwi Kayungyun, "Design and Implementation of Interactive Cyber Exhibition on Virtual Museum of Indonesia,", International Conference on System Engineering and Technology (ICSET), pp1-6, 2012a

[23] Stella Sylaiou, Katerina Mania, Athanasis Karoulis, Martin White, "Exploring the relationship between presence and enjoyment in a virtual museum," International Journal of Human-Computer Studies, Vol. 68, Issue 5, pp243-253, 2010

[24] Daniel Biella, Wolfram Luther, Daniel Sacher, " Schema migration into a web-based framework for generating virtual museums and laboratories," 18th International Conference on Virtual Systems and Multimedia, pp307-314, 2012

[25] Doug A. Bowman, Ernst Kruijff, Joseph J. LaViola, JR, Ivan Poupyrev, User Interfaces: Theory and Practice, Addision Wesley, 2005

[26] Jin Han Kim, Museum guide and management system using NFC, Master Thesis, Hallym University, 2013

[27] Jin Han Kim, Hanjae Jeon, Song Yong Sim, Sunwoo Lee, Changhee Lee, Young-Woong Ko, Chang Geun Song, “Museum guide and management system using NFC, MITA 2014, KMMS, Jul. 2014.

[28] Cho Young Suk, (Studying with video) self study 3D MAX 2013/2014/2015, yeamoonsa,

[29] https://developer.leapmotion.com/get-started/

[30] https://developer.oculus.com/downloads/unity/

[31] http://store.unity.com/kr/download?ref=personal

[32] http://www.archimuse.com/publishing/museums.html