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Participatory Behaviors and Interactive Experiences at a Science Museum**

과학관에서의 사용자 참여 행동과 상호작용적 경험

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Abstract

In allowing visitors to manipulate objects or models with their hands, science museums can become informal education institutions. However, little research has been conducted analyzing the specific interactions of visitors at museums and the effects that specific characteristics of interactive exhibit have on visitors. This research classified exhibits according to the three characteristics: the presentation of concepts, interaction with exhibits and concept levels. Further, relationships among engagement behaviors, visitors'attraction to exhibits, and the holding power of exhibits were analyzed. Using the three characteristics, 55 exhibits were classified into five styles. The results suggest that intriguing content and novel interfaces, maximizing information on science and technology, should be developed for the educational purpose of encouraging visitors to engage in active learning with interactive exhibits. The results of this study provide useful data that planners, designers, and instructors of science museums can use to maximize visitors' participatory learning and interactions.

Keywords

사용자 경험, 상호작용적 행동, 흥미유발, 참여행동, 과학관
User Experience, Interactive Behaviors, Attraction, Engagement, Science Museums

1. Introduction

Science museums are informal education institutions that can provide interactions beyond amusing visitors. Thus, exhibition spaces in science museums should not only draw visitors' interests, but also ensure that visitors spent an adequate amount of time at an exhibit so learning can take place.

Recently, an increasing number of "experience" exhibitions have been installed at science museums that combine innovative media technologies with educational purpose. Unlike traditional visual exhibits, these exhibits enhance the interactive learning effect by allowing visitors to touch and manipulate objects or models with their hands. Studies have shown that this new approach by science museums can increase visitors' interest, encourage direct participation, and lead to visitors gaining deeper understandings. These studies emphasize that the relationship between space and visitors is not a one-way interaction. The goal of science museums is to assist people easily to understand and learn about exhibition content in an interesting way. Interactive interfaces that use digital media emphasizing experiences have an important role in the process of learning and are likely to be used more frequently in the future.

To date, little research has been undertaken to identify the specific interactions between visitors and exhibits and to examine the effects of exhibit characteristics on visitors in an interactive environment. Thus, this study sought to examine visitors' participation behaviors by emphasizing

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experiences in new interaction spaces. Specifically, this study investigated the relationships among the characteristics of exhibits, exhibits' powers of attraction, their holding power and the engagement of visitors. The results of this study provide useful basic data that planners, designers, and instructors of science museums can use to maximize visitors' participatory learning and interactions.

2. Measures of Visitors' Behaviors in relation to Interactive Exhibitions

The following widely adopted measurement variables were used to analyze visitors' behaviors and interactions in exhibition spaces: attraction power(i.e., the exhibits at which visitors stopped) and holding time(i.e., how long visitors remained at an exhibit).[1)2)3)] Previous studies have measured the amount of time visitors talked to each other at exhibits, the time they spent interacting with exhibits and the time they spend reading exhibit material. These times are critical variables in visitors' interactions with exhibition spaces.[4)]

Attraction power refers to the percentage of visitors that stop at a certain exhibit and holding power refers to the average time that visitors spend observing or interacting with exhibits. Wolf[5)] argued that if visitors are interested in a certain exhibit and wish to interact with it, they remain at that exhibit for the continuous period of time necessary for the essential stages of natural learning. He further stated that future studies should seek to clarify what types of exhibition design encourages attraction power and holding power, resulting in natural learning. Some studies have shown that attraction power and holding power vary depending on the exhibition characteristics of museums. Peart[6)] noted that attraction power and holding power increased when sound or 3D-objects were added to exhibitions or when touching or manipulation(rather than just looking or reading a recorded explanation) was possible.[7)8)] Further, Chung et al.[9)] and Jeong[10)] stated that the augmented reality(AR) and direct experience of exhibitions also increased attraction power and holding power.

Recently, significant efforts have been directed towards investigating behavioral characteristics by observing and following the behavior of visitors to analyze more complicated and interactive participatory behaviors. For the most part, the engagement of visitors at exhibition halls appears to be related to viewing the exhibits, reading titles and instructions, touching and manipulating the exhibits or talking about the exhibits with others.

Van Schijndel et al.[11)] introduced the Exploratory Behavior Scale(EBS) as a measurement scale of children's interactions with the environment. EBS can measure users' exploration of their physical environment and classifies these exploratory behaviors into three levels: passive contact, active manipulation, and exploratory behavior. Similarly, Boisvert et al. 12 classified visitors' behaviors using the following three levels of participation to measure informal educational activities at places such as museums: involved time, positive interaction, and instructional time(i.e., how

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much time visitors devoted to an exhibit). Each of these levels of participation attempt to measure visitors' learning behavioral characteristics; that is, how visitors learn naturally by interacting with an environment in a particular physical setting.

This study sought to investigate the effects exhibit characteristics have on the participatory behaviors of visitors by observing visitors' behaviors in relation to exhibits at science museums. The participatory behavior of visitors was classified into levels based on the behavior codes proposed by Van Schijndel et al.[12] and Boisvert et al.[13](see Table 1).

<Table 1> Levels and Examples of Participatory Behavior

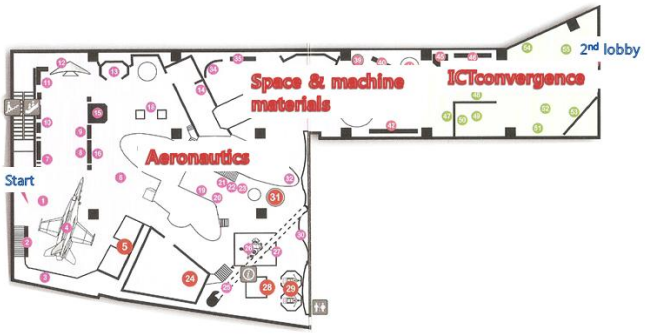
Type of Participation	Visitors' Behaviors
Level 1 Passive Contact	level 1-A: Looking closely at an exhibit, but walking on
	level 1-B: Standing in front of an exhibit or just looking at an exhibit without reading the directions or attempting to use the exhibit
	level 1-C: Watching other visitors use an exhibit, but not participating in any way
	level 1-D: Simply touching the exhibit, but not using the exhibit as intended
Level 2 Positive Interaction	level 2-A: Reading, listening to and observing the name or the details of an exhibit
	level 2-B: Reading and understanding the directions, and trying to use the exhibit as intended
	level 2-C: Devoting attention and interest to their own behavior and the movement of an exhibit in response to this behavior
	level 2-D: Attempting to engage in repetitive behaviors and changing behaviors when using an exhibit
Level 3 Cooperative Behavior	level 3-A: Observing or imitating the behavior of other visitors using an exhibit
	level 3-B: Using an exhibit with other people
	level 3-C: Discussing an exhibit's directions, significance and results with other visitors
	level 3-D: Reading and explaining an exhibit's directions or helping other visitors to use an exhibit as intended by handling the exhibit

The characteristics of participatory behavior were defined as: passive contact(i.e., visitors watching exhibits), positive interaction, and cooperative behavior. Passive contact, the lowest level of participation, comprised visitors briefly pausing(while walking) to look more closely at an exhibit, but not attempting to use the exhibit. The next level, positive interaction, comprised visitors stopping for a moment to properly use an exhibit for its purpose or performing repetitive actions to understand an exhibit's responses. Finally, the highest stage of participatory behavior, cooperative behavior, comprised visitors standing for a moment and cooperating with other visitors by having a conversation as they used the exhibit with the other visitors.

<Fig. 1> Engagement Behaviors
left: positive interaction; center: positive interaction;
right: cooperative behavior

3. Methodology

The research was conducted at Gwacheon National Science Museum, as it has exhibits that use innovative technologies and objects that support various experiences. Of the permanent exhibition halls of Gwacheon National Science Museum, the Advanced Technology Hall was selected because it was designed to allow visitors to experience the fundamentals of science and technology through inquiry using exhibits. The Advanced Technology Hall 2 houses aeronautics, space and machine materials, and information and communication technology(ICT) convergence experience content. It comprises 55 exhibits, including many airplane models of non-operating types that have not been changed since the museum first opened and more recent exhibits that use recent technological developments and have created an ICT convergence experience hall. Participants explored the 55 exhibits. The arrangement and location of the exhibits are shown in Figure 2.



<Fig. 2> The Arrangement and Location of the Exhibits

12) Van Schijndel, T.J.P., R.K. Franse, and M.E.J. Raijmakers, The Exploratory Behavior Scale: Assessing young visitors' hands-on behavior in science museums. Science Education, 2010. 94(5): pp.794-809

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Ten female university students of the same age and studying the same major were recruited as subjects for this study to reduce any personal preference discrepancies. Each participant experienced exhibits individually for one hour at different time periods without revisiting a same exhibit. Their behaviors were observed according to the characteristics of the exhibits. Participants were given one hour to explore the Advanced Technology Hall and the following was observed: the exhibits participants remained at, how long they stayed at these exhibits, and what type of behavior they demonstrated. Participants' behaviors were recorded by video so their behaviors could be closely observed and analyzed. Additionally, during their explorations, five investigators observed and recorded information; however, investigators were provided with basic guidelines to follow to maintain mutual trust. To obtain additional information on participants' interactive behaviors, an intensive interview was conducted with each participant after they completed their explorative participation of the exhibition hall.

4. Results

4.1. Exhibit Styles and Interaction

The Advanced Technology Hall 2 houses exhibits that are diverse, complex and provide different experiences. In relation to interactions with the space, the exhibits were classified using three characteristics.

First, exhibits were classified based on whether they could be operated by visitors directly or could not be operated; this depends on "How the Concept is Expressed." Second, exhibits were classified as having a low interaction if they could only be operated in one-way(e.g., seen or touched) or a high interaction if they could be moved by direct manipulations using various methods. Finally, exhibits were classified as having details that were easy for readers to understand or difficult to understand based on "the nature of the concept that the exhibit was trying to convey." The degree of understanding of university students were evaluated in terms of how much difficult they felt regarding the explanation or operation of the exhibits for the concepts.

The 55 exhibits at the Advanced Technology Hall were classified according to three characteristics and five styles(see Table 2). In relation to the exhibits, those that could not be operated, had low interactions, and easy concepts constituted the highest number of exhibits(i.e., 36.5 percent). Conversely, 29 percent of the exhibits could be operated, but had low interactions, and easy concepts. Compared to other museums, the Gwacheon National Science Museum has many operable exhibits. However, at the Gwacheon National Science Museum more than 76.4 percent of the exhibits were low interaction exhibits. Further, 23.6 percent of the exhibits were classified as Styles 1 and 3 and had high interaction levels.

<Table 2> The Three Characteristics of Exhibit Styles

N=55

	Exhibit Styles			Number of Exhibits (%)
	Presentation	Interaction	Concept	
1	operable	high	difficult	7(12.7)
2	operable	low	difficult	6(10.9)
3	operable	high	easy	6(10.9)
4	operable	low	easy	16(29.0)
5	non-operable	low	easy	20(36.5)

4.2. Visitors' Attraction to Exhibits

This study attempted to identify the exhibits that most attracted visitors. To do so, a number of factors were considered. First, participants had to interact with the exhibit for more than 10 seconds after first viewing the exhibit. The time was recorded as commencing when a participant entered the area of an exhibit and their eyes registered the exhibit. Eighteen exhibits(i.e., 32.7 percent of the exhibits) were found to attract participants' attention for more than ten seconds(see Table 3). These 18 exhibits included operating installations with different levels of interaction or exhibits across Styles 1 to 4. However, Style 5 exhibits(i.e., those that could not be operated) were found not to attract participants' attention for more than ten seconds. Thus, it appears that the presentation method of exhibits has a strong relationship with the initial attention of attracted visitors.

To compare how the styles of different exhibits attracted visitors the ratio between the total number of styles at the exhibition hall and the number of exhibits that participants were attracted to for more than ten seconds was determined. Further, the average time that participants spent interacting with each

exhibit was calculated. It was found that Style 1 exhibits were the most attractive exhibits with 57 percent of these exhibits drawing visitors' attention. Style 2 and 3 exhibits had the same percentage of attractive exhibits(i.e., 50 percent each); however, Style 3 exhibits had longer average viewing times of 153.2 seconds(a time 91.9 seconds longer than the average viewing time of Style 1 exhibits). Style 4 exhibits included only 43 percent attractive exhibits and had the shortest average viewing times. Thus, it appears that initial attraction has little effect on continuous interactions.

<Table 3> The Exhibits that Attracted Visitors

Exhibit Style	Attractive Exhibit	attractive exhibits/ total exhibits (percent) average viewing time
Style 1	Leap motion experience	4/7 (57%) 91.9 seconds
	Construction of an imaginary city of the future	
	Aircraft control	
	Lift and angle of attack	
Style 2	Mission control center	3/6 (50%) 83.4 seconds
	Smart window	
	Nano microscope	
Style 3	How would my movements be read	3/6 (50%) 153.2 seconds
	Future life with smart robot	
	HEMIRE	
Style 4	Mars exploration	7/16 (43%) 59.5 seconds
	International space station	
	Space shuttle	
	Magnetic levitation train	
	Elctroconductive fiber	
	Nano products for experience	
	Telescope	
Style 5	-	0

4.3. Holding Power of Exhibits

A comparative analysis was performed by recording the time that participants spend at each exhibit to identify their level of interaction. Table 4 sets out the results in relation to the exhibits that participants interacted with continuously(regardless of their behaviors) for a period of more than 60 seconds.

Style 1 exhibits had the greatest holding power with an average of 144.8 seconds, followed by Style 3 exhibits with an average of 134.4 seconds and Style 2 exhibits with an average of 129.3 seconds. Style 4 had the lowest holding power with an average of 89.5 seconds and no Style 5 exhibits had more than 60 seconds holding power. The exhibit with the highest holding power and an average of 285.0 seconds was the "How would My Movements be Read" exhibit. This exhibit had the greatest holding power across all ten participants and was designed to analyze movement by shooting infrared rays(invisible to people's eyes) from a sensor installed in a machine to compare the returning light. Visitors appeared to enjoy the experience of changing their body movements across a variety of contents such as sports or animations. The details conveyed by this exhibit led to it being categorized as a Style 3 exhibit; however, it is a very simple and easy exhibit that requires high interaction, as visitors use their entire bodies.

The "Mission Control Center" exhibit had the next highest holding power. This experience exhibit simplified the actual launch control center of the Naro Space Center. It was classified as a Style 2 exhibit, having low interaction, and requiring just a touch movement using a screen or button for activation. However, it had a high holding power with an average 176.7 seconds across all ten participants. The content of the exhibit was designed to launch the rocket of Naro directly and cooperation with other visitors appeared to continually attract visitors. The "Lip Motion Experience" and "Construction of an Imaginary City of the Future" exhibits encouraged participants to have an attractive experience with various details. The "Lip Motion Experience" was designed to simulate the repair of an underwater exploration robot or change the performance of a future vehicle using motion sensors. The "Construction of an Imaginary City of the Future" exhibit was designed to create a safe and advanced city of the future by solving problems such as energy exhaustion, environmental pollution, or disasters using science and technology of the future in AR. Both exhibits were classified as Style 1 exhibits and allowed participants to experience high interactions, provided feedback based on participants' changed movements and required direct manipulations(resulting in multiple interactions).

Operating exhibits had a holding power of more than 60 seconds. Style 1 or Style 3 exhibits with high interactions were found to provoke more holding power(i.e., 62.5 percent). Further, some of Style 2 and Style 4 exhibits with low interactions were found to provoke a holding power of more than 60 seconds (i.e., 37.5 percent).

<Fig. 3> above, left: “How would My Movements be Read”
above, right: “Mission Control Center”
below, left: “Lip Motion Experience”
below, right: “Construction of an Imaginary City of the Future”

<Table 4> Exhibits with Holding Times of more than 60 Seconds

Exhibit style	Exhibit Name	Participant number (person)	Holding Time (second)	Average Holding Time (second)
Style 1	Leap motion experience	10	160.6	144.8
	Construction of an imaginary city of the future	10	129.0	
Style 2	Mission control center	10	176.7	129.3
	Nano microscope	8	82.0	
Style 3	How would my movements be read	10	285.0	134.4
	Future life with smart robot	10	123.5	
	Rocket shooting	4	113.5	
	Digilog book	6	79.8	
	Designing my future car	8	70.6	
Style 4	Mars exploration	10	108.0	89.5
	Internaional space station	10	102.4	
	Dream into space	7	87.2	
	Airspace control system	6	82.6	
	Space shuttle	10	67.7	

These results suggest that museum visitors are more continuously attracted to exhibits when they can produce high interaction with the exhibits. It appears that level of interaction is a crucial factor in determining an exhibits’ holding power. However, the finding that some exhibits with low interactions still had holding power suggests that other factors such as the attractive contents of an exhibit can affect its holding power. The “How would My Movement be Read,” the “Lip Motion Experience” and the “Construction of an Imaginary City of the Future” exhibits all adopted context-awareness techniques and had holding powers of more than 100 seconds. These exhibits did not involve experience-based learning techniques(i.e., where visitors simply manipulate various objects); rather, they sought to enhance learning by providing appropriate details at visitors’ demands and the exhibits are used in relation to subjects or places that observe visitors’ behaviors or entire movements.

4.4. Visitors’ Interactive and Engagement Behaviors

The interactive behavior of participants was analyzed using the behavior codes of Van Schijndel et al. and Boisvert et al. The video footage was used to observe, code and analyze participation behaviors(see Table 5).

Participation behaviors with high frequency were classified as positive interactions under Level 2. Level 2A behaviors(i.e., the participant “Reads, listens to and observes the name or the details of the exhibit”) and Level 2B(i.e., the participant “Reads and understands the instructions and tries to use the exhibit properly as intended”) were the most common behavioral characteristics of participants using exhibits. Participants’ behaviors varied in relation to the exhibit styles. For Style 5 exhibits, most participants made passive, Level 1 contact. The most frequent behavioral characteristic was 1A, the participant: “Looks closely at the exhibit and walks by.”

<Table 5> Types of Engagement in relation to Exhibit Styles

Type of Engagement	Exhibit Style					Total (frequency)
	style 1	style 2	style 3	style 4	style 5	
level 1-A	0	0	0	4	97	101
level 1-B	0	0	0	0	31	31
level 1-C	0	0	0	0	0	0
level 1-D	0	0	0	0	30	30
level 2-A	45	60	29	68	10	212
level 2-B	50	35	36	90	0	211
level 2-C	50	5	30	14	0	99
level 2-D	50	26	35	20	0	131
level 3-A	21	0	14	16	0	51
level 3-B	11	5	6	0	0	22
level 3-C	0	0	5	0	0	5
level 3-D	0	0	0	0	0	0

Level 3, cooperative behaviors were infrequent compared to Level 2 positive interaction behaviors. However, there were more Level 3 participatory behaviors for Style 1 and Style 3 exhibits. Notably,

cooperative behavior was observed in relation to the "Launch Control Center"(Style 2) exhibit, "How would my Movement be Read?"(Style 3) exhibit and "Mars Exploration"(Style 4) exhibit, all of which had excellent holding power.

4.5. Visitors' Exhibit Preferences

Individual interviews were conducted after observation to identify participants' subjective preferences in relation to the exhibits. The following questions asked: "What were the most interesting exhibits and why?" and "What were the most uninteresting types of exhibit and why?" The participants were also asked to speak freely in relation to how they felt when using the exhibits. The results of participants' subjective preferences for the exhibits are set out in Table 6.

It was found that the exhibits that participants subjectively viewed as the most interesting were the exhibits that had the greatest holding power; for example, the "How would my Movement be Read?" exhibit had the greatest holding power and four of 10 participants stated that this was the most interesting exhibit. Participants noted that they could control this exhibit, had fun operating the exhibit by moving their body, and became absorbed in the exhibit, losing track as they played with well-known and favorite animation characters or played sports games with their friends. Participants appeared to prefer exhibits that required direct manipulation, involved simple and interesting movements, used interesting content, provided feedback, and required cooperation.

Four out of 10 participants stated that the "Conductive Fiber"(Style 4) exhibit was the most uninteresting exhibit. They noted that it simply required a button to be pressed, but that it did not work well even when the button was pressed. Further, their interest was quickly lost, as they could not understand the message that the exhibit was trying to convey. The interviews revealed that the reasons why participants felt bored included the exhibit's failure to work, the exhibit's simple button type, difficulties in understanding the exhibit's directions and message, and the large quantity of information composed of texts and photographs.

<Table 6> Participants' Exhibit Preferences

N=10

Question	Exhibit Name	Exhibit Style	Frequency (person)
The most attractive exhibits	How would my movements be read	style 3	4
	Leap motion experience	style 1	2
	Construction of an imaginary city of the future	style 1	1
	Mission control center	style 2	1
	Future life with smart robot	style 3	1
	Mars exploration	style 4	1
The least attractive exhibits	Elctroconductive fiber	style 4	4
	Leap motion experience	style 1	1
	Nano microscope	style 2	1
	Nano products for experience	style 4	1
	e-paper	style 4	1
	Spacesuit	style 5	1
	Return capsule	style 5	1

5. Conclusion

With the advancement of digital media, a number of science museums have recently begun to design interactive interfaces that afford visitors a variety of experiences. Previous research has simply classified visitors' behaviors based on one feature(e.g., operable vs. non-operable, learning vs. experiencing, or one dimensional vs. multi-dimensional). However, this research examined visitors' experiences and classified exhibits at the Advanced Technology Hall based on three characteristics: the presentation of concepts, interactions with exhibits and concept levels. The relationships among the characteristics of exhibits, engagement behaviors, visitors' attraction to exhibits and exhibits' holding power were also analyzed.

The results showed that visitors were attracted to exhibits for more than 10 seconds that required direct manipulation; that is, exhibits that involved touching, moving or grasping objects(as opposed to seeing or reading information) provided a more interesting experience for participants. Thus, it appears that interaction levels or concepts have little effect on visitors' attraction to exhibits and do not capture the footsteps of visitors. However, the direct manipulation features of exhibits were not sufficient to ensure the continuous interactions required to provide visitors with learning experiences. Operable exhibits often required only low-level interactions(e.g., simply touching a buttons) that caused discontinuity in participation behaviors and resulted in visitors losing interest, and ending their interaction with the exhibit. Exhibits with more than 60 seconds of holding power

required participants to manipulate their body movements in intriguing ways, could be simultaneously operated by friends, and provided continuous and proper feedback. These results suggest that rather than touch or the pressing of buttons, more advanced alternatives requiring high levels of interaction such as context-awareness and multimodal user interfaces should be installed in interactive exhibits to support visitors' participatory behaviors.

Participants demonstrated different engagement behaviors according to exhibit styles. For the majority of exhibits classified as Style 1 to 4 exhibits, participants changed their behaviors based on the exhibits' interactive responses to their own movements. Conversely, Style 5 exhibits only required participants to engage in passive contact, looking closely at the exhibit and thus resulted in participants walking onward. Style 1 and Style 3 exhibits afforded high interactions, greater social interactions(e.g., conversations and cooperative behaviors), and thus required multiple visitors to work together to simultaneously manipulate the installation.

Surprisingly, some exhibits with low interaction levels had significant holding power. When interviewed, participants noted that these exhibits sought to convey interesting content to visitors. Thus, it appears that interactive exhibits with intriguing content and novel interfaces should be developed for educational purposes to encourage more active and participatory learning and maximize knowledge and information in the area of science and technology. Further, current issues raised by participants based on their exploratory experience in relation to the interactive exhibitions could be addressed by ensuring the exhibits were easy to operate and manipulate. This study dealt with female university students as participants, thus the results would be different if participants are male university students.

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