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Exploring the Characteristics of STEAM Program Developed by Docents and its educational impact in the Natural History Museum

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ABSTRACT

The purpose of this study was to explore the characteristics of STEAM program developed and implemented by two docents and its educational impact for the use of natural history museum. Two docents developed this program with the help of science educators who ran five times of workshop during five months. The STEAM program implemented in the natural history museum demonstrated the following characteristics. The exhibitions in museum were reached by visitors only for learning science concepts (S) out of five components in STEAM. The other components, T (technology) and E (engineering), were delivered through lectures in the room, not exhibition hall. M (Mathematics)was achieved by guessing the animal's size, or calculating the walking or running speed with the clue of foot prints. The three phases of STEAM program (presentation of context, creatively design the investigation, and emotional touch) were explicitly implemented but partially successful. Two docents participating in this study responded that they formed new or extended the understandings about STEAM education, but they had the difficulties in implementing STEAM program for various type of visitors. All visitors who participated in this study displayed the favorable responses in educational impact by STEAM program in natural history museum. The heavier emphasis on E and T of STEAM program is recommended through community-based learning. In addition, educator professional program through which docents can bridge theory into practice is suggested for revitalization of STEAM education.

Key words : STEAM, natural history museum, docent, exhibition, visitors

Ⅰ. INTRODUCTION

We face that many issues full of benefits and challenges resulted from both globalization and a knowledge-based economy and scientific and technological innovations have become increasingly important in the 21st century (Chun, Jeong, Jeong, Lee, & Lim, 2012; National Research Council, 2011; 2012). In solving those issues we face, the skills of integrating knowledges to creative solutions are necessary along with various perspectives such as environmentally, economically, socially, and ethically (Baek et al., 2012; NRC, 2012; National Science Teacher Association 2013; Park, 2012; Yakman & Kim, 2007). More competent and creative persons are required to solve problems when redefining questions, framing questions to be investigated, designing the investigation, and collecting and interpret the data to be concluded with meaningful implication at the end with integrating disciplines (NRC, 1996; 2000; 2012). More than anything else, since technology as well as mathematics are pervasive in almost every aspect of daily life, the ability of integrating science with other disciplines (technology, engineering, mathematics) as one of core competencies is

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very critical to thrive in our highly technological world. Therefore, we can state that the goal of science education is to prepare students with core competencies of collaborating and communicating creatively in public awareness as well as obtaining subject matter knowledge. Students need to be more practical competent persons who can demonstrate core competencies necessary to challenge and solve problems they face rather than theoretical persons. To meet this goal, education policy in Korea as well as USA put the emphasis of STEAM (Science, Technology, Engineering, Arts, and Mathematics)/STEM implementation in current education system; in and out of the classroom (Baek et al., 2012; H. Park, 2012; Y. Park, 2012)

It is necessary to mention STEM in USA first before STEAM in Korea. The terms of STEM is now widely used in the world now but it was originally used by NSF(National Science Foundation) first. NSF used STEM term to include all education-related programs across NSF's different agencies, but it is now widely used in different contexts of meta-discipline which means an integration of formerly separate subjects into a new and coherent filed of study (Vasquez, Sneider, & Comer, 2013). Many researches have reported that students needs to be able to function and thrive in highly technological world to be STEM literate; identifying effective approaches in STEM is the "knowledge and understanding of scientific and mathematical concepts and processes required for personal decision making, participation in civic and cultural affairs, and economics productivity" (NRC, 2011, p5). Therefore, STEM literacy covers four different literacies to be integrated in cognitive knowledge, skills of experimental procedures and creative argumentation, attitudes to be a broad variety of viewer by adding, interconnecting, and applying these four disciplines to solve problems throughout person's lifetime, which starts to put the emphasis on classroom first. In addition, STEM education has been emphasized to meet the goal of science education for the decade in the USA but STEAM education beyond STEM has been focused in Korea as well as in USA nowadays (Baek et al., 2012; Y. Park, 2012; Riley, 2012; Sousa & Pilecki, 2013). STEAM include 'Arts' in addition to the components of prior STEM. 'Arts' is defined in the field of 'liberal arts' including 'fine arts', 'physical arts' and 'language arts', and 'Arts' is also exaggerated as one of critical factors to be creative (NSTA, 2010; Park, 2012; Sousa & Pilecki, 2013).

The educational impact of STEAM has been reported in many areas as follows. Students' interest in doing science has been increased (Kang et al., 2010; Chung, 2012; Y. Park, 2012). Students who took the STEAM program displayed preference to the certain professional occupation introduced in STEAM program, indicating that the higher preference to professional career students have through STEAM program, the higher academic achievement as well as attitude to science students show (Yun et al., 2006; Y. Park, 2012). In addition, students' self regulation ability in learning has been increased (Kang et al., 2010). Students' abilities to solve the problems creatively through the integrated thinking skills (Sanders, 2009) with the use of technology in collaboration have been promoted. These educational impacts on students through STEAM program have been researched in the context of real classrooms in Korea. Surely there have been researches releasing the positive impact on teachers' practices through STEAM program.

When preparing scientifically literate citizen through STEAM education, learning context out of the classroom as well as in the classroom needs to be researched to see how STEAM program can be implemented and what impact STEAM program can be given on leaners, since students are exposed to learning contexts in or out of the classroom at the same time. The teaching and learning science out of the classroom is an informal setting of learning and science museum (including science center) can be representative (Falk & Dierking, 1992; Jung, 2010; Park & Lee, 2011, 2012), therefore, active implementation of STEAM program in science museum is another essential to reinforce STEAM education in Korea. To meet this goal of reinforcing STEAM education in the context of science museum, the following two points must be considered. First, there is little research about STEAM program implementation in science museum, so providing exemplary case of development of STEAM program and its application into science museum may suggest the development direction of STEAM education in informal learning context as well as formal one. Second, since there is not well prepared educator like docents who directly interact with visitors who could develop and implement science program into the context of science museum (Park & Lee, 2011, 2012; Lee & Park, 2013), it is suggestable to provide professional development program to equip docents to be expertise in theory and practice of STEAM education. On the basis of two conditions (case of STEAM program by trained docents), the researchers in this study helped two docents to develop and implement STEAM program in the context of science museum and investigated what characteristics of STEAM program in science museum could be withdrawn and how participating docents could become experts in STEAM education.

Ⅱ. RESEARCH METHODOLOGY

There are three stages where the researchers did investigation to answer the research questions (Fig. 1).

In the first stage (Development of STEAM program), the researchers contacted two docents by convenience sampling. Two docents, Docent Park and Kim, had almost 10 years working experience at 'A' natural history museum and their main roles were interacting with visitors through touring exhibitions and running educational program. The researchers ran five times of workshops (once per month) through which two docents began to learn what STEAM is, why people pay attention to STEAM education, what components of STEAM is composed of, what strengths and weakness of STEAM program in the classroom are, how they can use exhibition of museum for STEAM program and so on. Two docents and three researchers interacted each other through off-line workshop and on-line email when necessary. The title of the developed STEAM program was 'The footprint is black box'. The researchers collected the data related to two docents' understandings about STEAM education through survey and conversation at this stage of research. The main points of STEAM program emphasized by the researchers were that five explicit disciplines of STEAM must be included and three opportunities of learners' recognizing the context, designing the investigation, and experiencing the emotional touch.

In the second stage (Implementation of STEAM program), two docents implemented STEAM program two hours long into the setting of 'A' natural history museum and interacted with visitors (consisting of four beginning docents, 15 students, and eight adults) at the exhibitions hall as well as the lecture room. Two do-

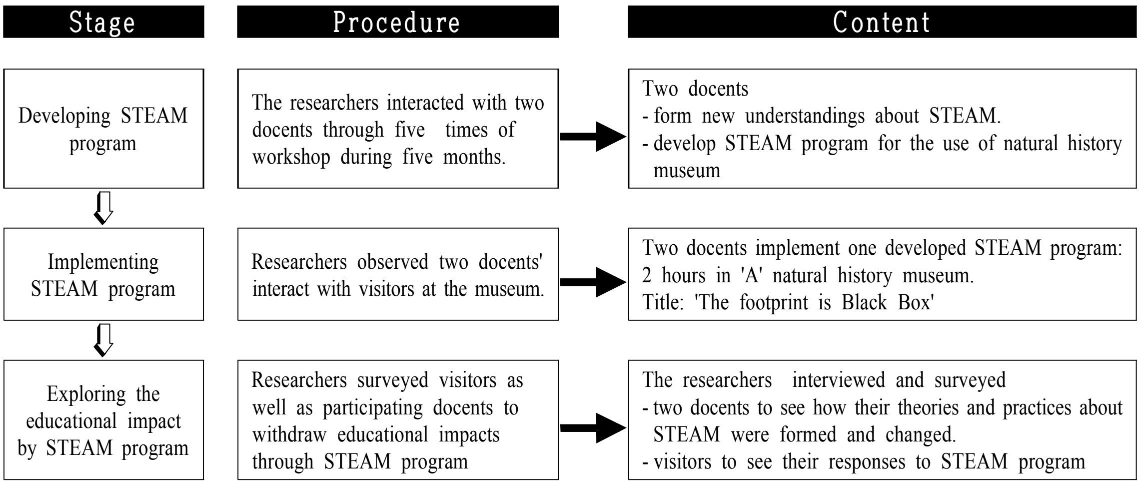


Fig. 1. Research procedure.

cents shared the roles of one (Docent Kim) leading the visitors in the lecture room and the other (Docent Park) touring visitors in the hall of exhibition. The researchers observed how two docents interacted with visitors and recorded their interactions by video. All verbal practices were transcribed and all physical practices were observed to be used as one of evidences supporting researchers' claim through triangulation.

In the third stage (exploration of educational impact of STEAM), the researchers explored the educational impact on visitors as well as participating docents after STEAM program. The researchers developed two different surveys for visitors and two docents and they filled out the surveys after STEAM program two hours long. Unstructured interview was also conducted for the groups of visitors and two docent who led the lesson. All survey and interviews were aimed to see if STEAM program was influential to visitors. All Interviews were transcribed and surveys was also analyzed to be used as evidences for revealing what educational impacts on visitors and two docents by STEAM program were emerged. The validity and reliability of data collection and data analysis were constructed by researchers' discussion to be consensus through cross checking.

Ⅲ. RESULTS

The characteristics of STEAM program developed and implemented by two docents for the use in the natural history museum were explored and its educational impact on visitors as well as participating two docents were investigated. The results of this study were described according to each research question.

1. The Characteristics of STEAM Program in 'A' Natural history Museum

The researchers used four different analysis to make decision how well STEAM program has been developed to meet the goal of scientific literacy as follows; (1) whether all five components of STEAM was included in the program, (2) whether the STEAM program consisted of three opportunities of 'recognizing the real problem' to solve, 'designing the investigation' creatively to solve the problem, and 'experiencing the emotional touch' such as feeling interest, self-efficacy, self-confidence, and sense of accomplishment to promote their learning. All of emotional touch covers all positive emotions in doing science (Baek et al., 2012), (3) how STEAM program can be differently implemented in the natural history museum according to various levels of visitors, and finally (4) how often science exhibitions in the natural history museum can be utilized during STEAM program.

1) The five components of STEAM program in the natural history museum

The title of STEAM program implemented into 'A' natural history museum was 'The footprint is black box', whose story dealt with one mammal which left the footprint in falk village. The task was to find out what kind of animal came down to damage the crops and how the village people would prevent those animals from damaging the crops. The following overview in STEAM program indicated that the five components of STEAM were successfully included.

[S] We can recognize the animal's structural features, its walking speed and size, and its moving style on the basis of appearance and size of animals' footprint when compared to mammalian species. **[M]** Guessing the size of the mammal can be predicted depending on the size of footprint or the size of stride, which is connected to that of human being **[E]** to find out the principles applied to the technology in sports-engineering, and **[A]** Footprint is analyzed through environmental factor for the classification of mammals and through daily life factor for its adaptation, all of which can give clues for us to infer and describe the story of how the footprint was formed through physical experience activities. Finally, **[T]** we can discuss technically the way of developing wooden fence to reduce the damage made by the mammals, or we can analyze the reason why the mammals recently increase to come down to the private houses to harm damage , then we can find ways to preserve the environment and protect the crops from animals' damage.

[S] science [T] technology [E] engineering [A] arts [M] mathematics

The STEAM program developed by two docents

Fig. 2. STEAM implementation in lecture room and exhibition hall

displayed that five different components of STEAM have been well embedded in this overview. More details about how five components of STEAM were embedded as follows.

Science: Visitors participating in this study, at first, observed different stuffed mammals displayed in the exhibit hall, where they could gain general information about each mammal and its inhabited environment (Fig. 3).

Technology: People in the village suggested to install electric fences to prevent the mammals from harming damage crops in the farm. Docent Park introduced what problems the people in the village faced and how they could solve the problems with the use of real photos and maps (Fig. 4).

Fig. 3. The component of STEAM : science

Visitors needed to discuss where electric fences would be installed on the basis of information about the kind of animals and their sizes.

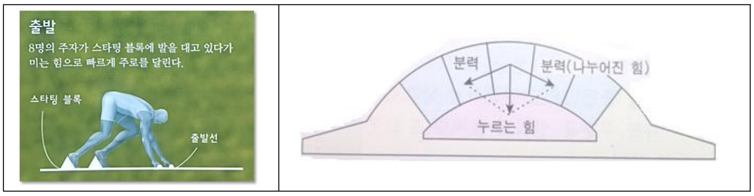
(The upper map describes the tracks of wild pig which damaged the farm.
The two bottom photos show the electric fences built to reduce crop damage by wild pig. Those electric fences are supported partially by the city and this project is conflicted by the association of wild animal protection)

Fig. 4. The component of STEAM : Technology

Engineering: The style of walking or running can be inferred from the footprints left on the farm. The shape of footprints can look different when walking or running and they can recognize which animal is good at running or jumping with the shape of footprints. This inferred knowledge can be applied in designing the athletics' running shoes overcoming their flat-footed. This chance of introducing 'engineering' of STEAM can stimulate any student of visitors to have interest in becoming athletics' shoes designer as career guidance (Fig. 5).

Arts: The arts of STEAM means the followings; fine arts, language arts for communication, liberal arts such as sociology, history, and politics, and physical arts such as sports or dance. Arts in the STEAM program in this study included creative activity through which students at lower elementary level express their ideas with their own language. Participating two docents introduced another 'arts' through which adults or students in high schools write a poem or story with the theme of footprints (Fig. 6).

Soccer player of Korea, **Jisung Park,** is **flat-footed** which is the worst for soccer player. There is the arch of the foot for normal people but it is not for people who are flat-footed. These people with a flatfoot are divided into two groups. Some people are flexible flat-footed and their arch of the foot works normally when seated but abnormally when standing. Others who are rigid flat-footed are suffering from joint pain by nature or other reasons of athletics joint. Normal people's arch of the foot can absorb the impact from walking or running, but people who are flat-footed don't have this absorbtion much so they cannot do sports very well. This flatfoot is also a problem for the soldiers who need to walk for a long time. Bongju Lee, who was a marathon runner, was also flat-footed, so the sports company designed special running shoes for cushioning the impact.



Docents introduced the principles and skills which can be applied in sports-engineering for athletics. Docents shared the story how athletics overcame their barrier of flatfoot to be the best runner or player. Special designed athletics' shoes are introduced.

Fig. 5. The component of STEAM : Engineering

Kids at young age designed hanker chief by stamps of various animals' footprints. Kids can classify the animals by footprints' size and shape.

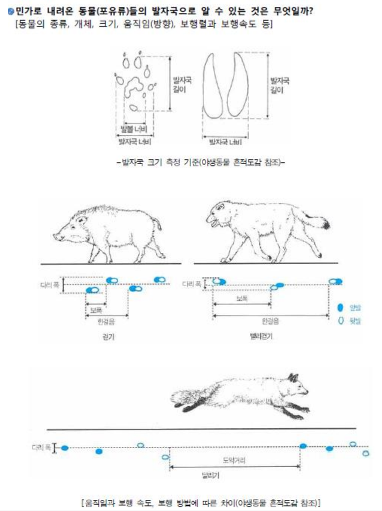
Kids do activity of coloring: green color for grass-eating animals, red color for carnivorous animals

Visitors at young age could do activity to make t-shirts by stamping footprints and create its story.

Fig. 6. The component of STEAM : Arts

Mathematics: Students at young age in this study could calculate the size of animals by even strides from footprints left in the farm. Students in middle or high schools could calculate the walking speed as well as inferring animals' moving direction with the use of footprints (Fig. 7).

Generally, the STEAM program (its title was 'footprints is black box') implemented in the natural history museum included five components, S, T, E, A, and M with different weight, SteAm program (strong S, A, and M, but weak T and E). Participating two docents introduced much knowledge about the characteristics of animals (all about animals by using the stuffed animals in the exhibition hall) by interacting with visitors, who observed foots very carefully to solve the given problem. Visitors also had chances to *infer* habitat environment of animals displayed as the stuffed ones in the exhibition hall and *communicate* their findings with other visitors. Visitors also guessed size of animals, calculated walking or running speed with the use of footprints. 'S' and 'A' as well as 'M' can be emphasized much in the STEAM program implemented in the natural history museum. However, how to design athletics shoes overcoming flat-footed fault and how to install electric fences preventing animals from invading and eating the crops in the village were introduced verbally only in the lecture room of natural history museum without any activity. Therefore, STEAM program of 'footprint is black box' was what S, A, and M components are more weighted and T and E components



Docents asked visitors what they could know from the footprints left in the farm. The answers included the type of animals, its size, its moving direction, and its walking speed. visitors could compare the animals' size, infer animals' moving behaviors by comparing even strides of footprints left in the farm. Docents guided visitors to infer what they could know as much as possible with the use of footprints.

(The drawing in the left describes what and how we can guess from the clue of footprint. We can guess the kind of animals from the width and length of footprint, its size, its moving direction, and walking and running speed from the strides of footprints)

Fig. 7. The component of STEAM : Mathematics

are less weighted (Bybee, 2013).

2) The three phases of STEAM in the natural history museum

STEAM program is expected to provide the following three opportunities for the successful STEAM one. First, visitors need to be aware of what problems they face and feel responsibility to solve the problems in the given 'presentation of context'. Second, visitors need to have chance to 'design the investigation creatively' to find out the solution. Third, visitors 'experience the emotional touch' by doing science and engineering. These three opportunities do not have to come as a sequence, but usually they happen as a sequence. The details of how three phases are embedded in the STEAM program as follows.

Presentation of Context

First, docent Park introduced the current issue through the environment report as well as video, which illustrated that the farmers had damage on their crops from the appearance of wild pigs and motivated visitors to have interest in those mammals (Fig. 8).

In this phase of STEAM, visitors had chance to be aware of what the problem was and they felt responsibility to save the crops from the wild animals. The following excerpt explained how docent Park interacted with visitors by motivating them to **recognize** the problem they faced.

Docent Park: *since my husband also runs the farm, I became to know that the crops were damaged by the wild animals. I found this article from the newspaper saying that there were many wild animals damaging the crops (showing the article to the visitors) [omitted] As you know, wild animals damaged the crops, actually my husband harvested the half of sweet potatoes which he expected to do due to wild animals. I felt that I need to find out the 'reason' of why wild animals came down to the village to damage the crops and felt responsibility to find out the solution to save the crops. What do you think? Why did wild animals come down to the village? Is this footprint wild pig's or what? These footprints are marked down to the village? Which way is this animal moving? How can we stop this animal from coming down from the mountain? Can you find the solution so that I can tell it to my husband?* **(Docent Park's introduction of presentation of context in STEAM program, where visitors were recognized the problem).**

Docent Park tried to motivate visitors by connecting the problem to the daily life through which they were stimulated to find out the solution. In addition, Docent Park motivated visitors (especially students) to have interested in dealing with this problem by providing more detail questions so that visitors could answer easily with their own prior knowledge. The following conversation indicated how docent Park stimulated visitors to be interested in understanding the problem in detail.

1. Presentation of Context
why footprints in the farm?
This is the report in the session of environment column. visitors became to know why the crops in the village were damaged and recognized the footprints in the farm were the clue for this damage. Visitors were guided to discuss which animals' footprints could be inferred, what evidence could support their findings, and how they could prevent those animals from damaging the crops.

Fig. 8. The phase of STEAM : Presentation of Context

Docent Park: *All animals walk by four foots? How can we know animal's size only by the footprints left in the farm? Ok let's measure how big your foot size is. I have string ruler, OK, what about you? You seem to have 200 mm of shoe size, so your real foot size will be 180 mm?*

Visitor A (student): *Yes, my foot size is 180 mm.*

Docent Park: *180 mm? OK, then would you stand up please? I wonder how tall you are. I will measure your height. I got 70 cm from the foot to your waist. Anybody can calculate what number you need to multiply to your foot size to get this number?*

Visitor B (student): *around four times?*

Docent Park: *OK, you got this number after multiplying four to this foot size. Then we can get the height from the foot to the hip of this animal by measuring the length footprint? We can guess animal's size with the footprint? What do you think?*

(Docent Park stimulated students to be interested in understanding the problem in detail with their own prior knowledge).

Next, two docents guided visitors to be more logic and knowledgable to solve the problem. Visitors had chances to use their prior knowledge to understand the problem logically and scientifically as follows. Visitors became to know the kinds of animals, their size, their characteristics, and their habitat environment from the footprints left in the farm and visitors also compared different footprints to have various information related to various feet. Visitors started to make decision which animal was the main invader to damage the crops. This presentation of context phase was run by two docents alternatively in the lecture room.

Creatively Design the Investigation

Two docents guided visitors to the stuffed mammals in the exhibition hall and visitors in groups were asked to confirm what they discussed in the lecture room and made decided what kinds of animals were invaders to damage the crops only by the footprints. Visitors in groups observed the stuffed mammals, decided which one might be the invader to the village, and what solution visitors could suggest to protect the farm from wild animals. Visitors inferred which animal damaged, what kind of animal was, if that animal was fast runner, if that animal was slow walker, and how tall they were. Visitors drew the map and decided how long the fence must be, how tall the fence must be, if the fence must be wooden one or electric one, and such as. Two docents at this time introduced if visitors could find the flat-footed from the footprints left in the farm and asked them what would happen to the athletics if they would be flatfoots. Docent Kim talked about how soccer player, *Jisung Park,* could be best player and how marathon runner, *Bongju Lee,* could be best by overcoming their flatfoots. However, this interaction was implemented verbally only by showing the photos or drawing without real practical implementation of engineering or technology. In addition, the chance of introducing 'engineering' of designing the shoes for athletics was not related to solve the problem in this STEAM program. The following interview and responses from survey released how hard two docents were struggling to embed 'technology' and 'engineering' into the STEAM program.

Docent Kim: *I had difficulty in connecting the issue of footprints to the components of engineering. The introduction of using engineering for athletics' shoes was fun to share with visitors but this was not related to the footprint issue. I am sure that I knew that engineering component of STEAM program is very essential one but I am not sure yet how to include it naturally into STEAM program and how to relate it with the current issue we are dealing with (Interview with Docent Kim)*

Question: What was the most difficult in developing and implementing STEAM program?

Docent Park: *I wanted to keep visitors motivated in their learning, but I felt there was disconnection in their learning when I introduced the part of 'engineering' in the footprint STEAM program. The* *story of athletics' shoes designed ergonomically was pretty good to make visitors interested in this program of STEAM and I thought that I was successful to include each component of STEAM into one. I liked the story of engineering part of athletics' shoes applied by the story of footprints, which was really interesting, but it was not used directly for solving the problem. So what? This is OK or not? (From the survey of Docent Park)*

Docent Kim: *We (two docents) worked together, we were very confident to talk about the characteristics of animals for science, their walking speed or their size calculating for mathematics, and inferring habitat environment from the footprints as well as making shirts with footprints' stamps for arts. However, we just covered engineering and technology of STEAM verbally without any practice. The lecture[about athletics] was pretty interesting to visitors, but I wonder if I can say this is STEAM program (From the survey of Docent Kim)*

Two docents responded that engineering and technology components of STEAM were the most difficult one to include into the STEAM program by covering them verbally only without concrete practices through activities. In addition, two docents wondered if all components of STEAM must be connected to the process of finding out the solution. Two docents mentioned that all components except engineering were connected each other to prevent animals from damaging the crops, but they believed that engineering of STEAM program was used only to motivate visitors to have interest in principles related to flat-footed to design ergonomic shoes for athletics. Two docents also mentioned to build electric fences with appropriate length and height verbally with visitors. Therefore, engineering as well technology of STEAM in the natural history museum was not practical through activity but learned by visitors verbally with much interest during the phase of 'creative design investigation'.

Emotional Touch

There was another phase of STEAM, 'emotional touch' phase where visitors were expected to understand science learning by hearts (Park, 2010). In this phase, visitors could learn positive attitude toward science, form positive self-efficacy, develop alternative perspective of science such as societal one, political one, and economic as well as environmental one. First, visitors as a group or in a team created the shirts or handkerchiefs with different stamps of footprints; different coloring stamps for different characteristics of animals. Young students began to learn animals' habitude, such as grouping, food chain, and migrating and adopting themselves to new environment by printing different coloring stamps of footprints as well as creating stories related to animals' lives.

Second, visitors in a group or as a team were also guided to suggest how to stop animals from coming down and damaging the crops. At this point, visitors needed to consider the following some conditions before installing the electric fences. If the animals are reduced in their number, what would happen to food chain? What position of people in the farm will be about building electric fences? What position of ecologist will be? How can we regulate their positions each other? Visitors could learn alternative perspectives when understanding science, which is possible by hearts, not by mind nor by hands (Park, 2006). Two docents guided this opportunity of emotional touch in STEAM program with visitors in the lecture room at the end of program. Two visitors (father and son) presented their suggestion of how to stop animals from damaging the crop and they also commented pros and cons in installing electric fences for farmers. Economic as well as environmental views needed to be considered to install the electric fences as a solution in this program.

3) Various teaching strategies according to various levels of visitors

The STEAM program included a few different teaching strategies for various levels of visitors ranging from the young to the old. In the phase of creatively design the investigation, visitors (students at high school levels) had chances of using scientific principles related to the flat-footed to design the ergonomic shoes even though implemented verbally. Two docents and visitors, first, discussed the effectiveness, appropriacy, accuracy, and felicitousness of shoes for flat-footed. Then, visitors sketched their own designed shoes with the considerations in its shape and size briefly. Visitors of high school students at this point could think of becoming engineering designer or biomechanics to produce athletics' shoes. This STEAM program could work as a good resource to motivate visitors of students to have interest in the field of natural science and engineering as occupations. Visitors of young learners estimated the animals' size but students at middle or high school students calculated the exact size from the size of footprints mathematically. Young students created the story by printing various of animals' foot stamps in terms of fine arts but adult created the poem or story related to footprints in the woods in terms of liberal arts. Visitors of adults discussed the pros and cons of installing electric fences with alternative views; economically, ecologically, and personally as a farmer or an animal lover. Two docents stated that it would be very critical for people to take actions of human activity on nature including animals, which was one of remarkable features of STEAM program. However, two docents mentioned that it is always challenging for them to interact with various level of visitors with different teaching strategies even in implementing STEAM program. The following excerpt from interview described the difficulty of interacting with visitors who were demanding different knowledge and interest.

*I could not have enough time to figure out what type of visitors came for STEAM program. I ran STEAM program with the focus on family type of visitors and I made family have interest in footprints left in the farm and to observe feet of the stuffed animals in the exhibition hall. Their mission was to fill out the worksheet by inferring the characteristics of animals from footprints and completed the activity of making shirts with the footprint stamps. This was low level targeting to family unit only. In a way, I failed to regulate different level of program with various type of visitors (**Docent Kim's response to the question in survey)***

4) The exhibit availability in natural history museum for STEAM program

At the early state of STEAM program, two docents actively used the exhibitions displayed in the hall to stimulate visitors to pursue the solution and get them knowledgeable about mammals. Two docents questioned visitors of the features of the stuffed mammals displayed in the type of diorama and let them observe and infer the relationship between footprints left in the farm and the stuffed feet of mammals (Fig 9).

Two docents also helped visitors fill out the worksheet of mission and perform the activity of book art, which made visitors understand the concepts of mammals whose feet could be very good evidence to infer their biotic habitat and environment (Fig. 10).

The frequency of using exhibitions displayed in the

Docent Park explained the relationship between foot size and body size with the use of the stuffed animals in the exhibition hall.

Fig. 9. Two docents' interaction with visitors in the exhibition

Young visitors in a group performed their assigned worksheet of mission

Fig. 10. Visitors' mission to fill out the worksheet by observing the exhibit

hall was very low since two docents used the exhibition to deliver the ‘concepts’ in ‘S’ related to mammals only to visitors at the early stage of STEAM program. When two docents tried to implement other two components of STEAM, ‘E’ for athletics’ shoes and ‘T’ for electric fences, they could not use exhibitions appropriately. Visitors moved to one of lecture rooms to calculate the walking speed or body size from the size of footprints left in the farm and two docents explained the implementation of ‘E’ and ‘T’ verbally only without any hands-on activity, such as sketching or designing shoes fit for athletics whose feet are flat or installing the electric fences which could stop the animals from damaging the crops. Therefore, the stuffed animals of exhibitions were used mainly for delivering concepts/information in STEAM program overall.

2. Educational Impacts of STEAM Program on Visitors and Docents

Two educational impacts by STEAM program developed and implemented by two docents in one of natural history museum were released as follows. One educational impact was on two docents and the other on visitors participating in this study.

1) Educational impact on participating two docents about STEAM education

First, **two docents responded that they newly formed and extended the pre-existing perception about STEAM education.** At the beginning of this study, two docents were told that STEAM education is very pivotal educational policy by media and they were asked to implement STEAM program into science museum they belonged to. The reason why two docents were involved in the workshop run by the research team was that they were eager to learn more what STEAM would be and how it could be implemented in the setting of science museum. Two docents became knowledgeable of what components of STEAM were essential and how they could implement it. Docent Kim indicated that keeping visitors motivated in finding out the solution was very challenging but important in STEAM program by providing the familiar learning situation, which was also emphasized in STEAM of PBL (Project Based Learning) approach (Stanley, 2012) for its success implementation in the classroom.

For the success of STEAM program, I found out that it is very critical to stimulate visitors to pursue the solution by giving them real problem or issue possible in their daily life. So I used the current issue from newspaper which visitors might be familiar with and I tried to use the mammal exhibition in the hall to get them be knowledgeable as much as they could before brainstorming of how to solve the problem. First of all, I think that it is essential to make them exposed to the situation of problem by letting them reminded of concepts well known to them ***(Docent Kim’s response to the question in survey)***

In addition, two docents perceived that 'A' of STEAM does not mean 'fine art' only but all possible areas including liberal arts and language arts as well. Two docents tried to implement the activity of printing shirts or handkerchiefs by stamps for 'A' part of STEAM, but they developed another activity for 'A' for adults and students at high school levels, who inferred what biotic habitat and environment situation could be withdrawn and what kinds of animals could be surviving in those areas or who performed the activity of writing a poem or essay with the story of animals whose footprints were left in the farm. The following excerpt from interview by docent Park indicated that there was extension of her perception about STEAM program.

I thought that we need to produce the concrete products through hands-on activity at the end of STEAM program. That's why I planned to implement stamp printing shirts and handkerchiefs at the beginning, but I became to learn that inferring thinking skill and writing skill can be also the products of 'A' in STEAM program. I am not much confident to deliver these skills of inferring and writing to visitors professionally but I at least tried to do this time. I am very proud of myself. I feel I did great job of STEAM program in museum ***(Docent Park's interview).***

Secondly, **two docents indicated that their perception and knowledge about STEAM program were more actively formed and changed through practices of developing and implementing STEAM program by interacting with the researcher team.** Two docents added that it would not be possible for them to be confident of developing and implementing STEAM program unless they had learned how to implement it through its real application with the researchers' help. Two docents struggled to develop STEAM program with optional teaching strategies demanded by various level of visitors and they selected and employed strategy appropriate for the family unit of visitors. They responded that they were successful in implementing STEAM program to some as planned but in a way they failed to do. The following excerpts from two docents' interviews supported their perception changed or maintained through their practices of developing and implementing STEAM program (Fang, 1996; Park, 2008).

In another way, STEAM program is very good for us to implement it into science museum full of various type of visitors. I could employ 'A' of writing to students, 'A' of inferring to adults' and 'A' of printing shirts to young kids for perfect STEAM. This is what I preplanned and I felt safe when this happened naturally while I was interacting with all visitors during the class ***(Docent Park's interview).***

I intended to deliver much concept for visitors during STEAM program, which was possible while visitors observed the stuffed animals in the exhibition hall. I was active in explaining mammals' features to visitors, but I could not use any exhibition at all when I talked about math, technology, and engineering part. So I thought that I completed STEAM partially. As you mentioned before, visitors seemed not to understand the parts of technology and engineering completely without concrete practices of hands-on. Some happened as planned, however others did not happen as planned. I was right in a way and I was wrong in another way ***(Docent Kim's interview).***

Thirdly, **two docents put the emphasis of running professional development program for experts in successful STEAM education of science museum.** Two docents responded that it was possible for them to develop and implement STEAM program with researchers' help. They figured out that STEAM program could not be perfect at the current educational situation of natural history museum, so there must be another help from engineering or technology experts for the practical STEAM education. Without those experts' help in engineering or technology, two docents stated that they could only make unbalanced STEAM program, with more weighted science and art and less weighted technology and engineering. The following excerpt from interviews supported this claim.

I can help other docents when they ask me about STEAM program now. I am the leader of docent groups and I feel responsibility for training them about STEAM education which has been emphasized in the country for the years. Educational policy puts the emphasis of implementing STEAM program into science museum as well as classroom. But how? We are the very persons who interact with visitors in science museum, but we do not know how to develop and implement STEAM program. We did not have a chance to take workshops or courses for being experts in STEAM education. But I was lucky to meet you and I was trained to do this job. I expect other educators like you to offer professional development as we did through workshop for STEAM education in science museum ***(Docent Park's interview).***

2) Educational impact on visitors participating in STEAM program

Four docents, eight adults, and fifteen students visitors were surveyed and interviewed as a group about asking educational influence by STEAM program and the following results were developed from data analysis. All participants agreed that STEAM program was successful in motivating them to feel responsible in finding out the solution and saving the crops. All visitors also responded that STEAM program was very attracting them to keep researching their assigned task and they added that it was fun to observe exhibition displayed in the hall with the shared certain purposes as a group.

I like science learning in museums better than in classroom. I had more chances to talk and ask questions to teachers [docents in this study]. I enjoyed today's activity and I felt like a detective or scientist when I used footprints as evidence to infer which animals were coming down to the farm. It was interesting to calculate body size with the use of foot size. It was awesome that athletics could overcome their weakness of flat foot with the engineered shoes. It was interesting to know which footprints were flat ones or not ***(positive educational impact on one of students from his survey).***

I used to sit in the coffee shop whenever we visit science museum when my kid was busy in doing something in science center, but I joined the group of visitors today and I helped my son to do better in his mission task. I could explain my son what to present after observing exhibitions in the hall. I also presented what I observed in the exhibition hall. My son did not know who Bongju Lee, marathon runner, was. My son asked me who he was when we were chatting about which animals' foots are good at running fast or jumping high such as ***(One parent's interview).***

Four docents who were participating as visitors showed their educational impact as follows. At first, four docents were unfamiliar with STEAM education but they became to learn what STEAM program looked alike and what professional skills they needed in implementing STEAM program.

It was good opportunity for me [one of docents as visitors] to see how STEAM program was implemented by two docents who were much more able persons when compared with us. We were asked to develop lesson plan of STEAM program for using it in our museum, but frankly I don't know what STEAM is and how we develop and implement it. Now I have passion to learn more about STEAM program and I am confident to develop STEAM program after watching two docents running STEAM program. I hope to have professional program in this center so that docents like me could have chance to learn STEAM education ***(One docent's interview in a group of visitors).***

Overall, we can state that STEAM program had very positive impact on visitors on the basis of their responses. All visitors showed consensus that STEAM education could produce the talented persons as envisioned in *Standards* (NRC, 2012; 2011) and Korean STEAM educational policy by responding that they could be more creative (23 out of 27), they could learn more skills related to solve the problem from daily life

(25 out of 27), and they could build more upright character through STEAM program (23 out of 27). Participants also responded that they had fun in learning more concepts about mammals and learning how to infer some information from their observations.

Ⅳ. Conclusions and Implication

First, **the heavier on engineering and technology through practical hands-on activities must be emphasized for idea STEAM program in the natural history museum.** Two docents were confident in explaining features of mammals with the stuffed animals displayed in the exhibition hall, which was targeting for 'science'. Visitors had chances to estimate the size of animals or calculate the walking speed from the footprints, which was targeting for 'mathematics'. Two docents used two different strategies for 'arts', printing the stamps of various footprints with young kids and inferring biotic habitat and environment situation with adults. However, two docents interacted with visitors for 'engineering' and 'technology' by designing athletics' shoes and building electric fences verbally. Therefore, more weighted 'E' and 'T' of STEAM must be included for the successful STEAM education in the natural history museum.

Second, **the STEAM program in the natural history museum can contain strong science concept part connected to the exhibitions.** Two docents used the stuffed animals displayed in the exhibition hall to encourage them to connect concepts from exhibition to their prior concepts necessary to understand the problems they faced fully. The exhibitions in the natural history museum containing exhibition panels were used for 'science' concepts, which made two docents interact with visitors actively in the area of exhibition hall at the first stage of STEAM program, 'presentation of context'. The other 'E', 'T', 'M', and 'A' components were learnt in the lecture room. If STEAM program is implemented in science center full of many hands-on tools or equipment, 'E' or 'T' can be easier to include than others. Therefore, the consideration of which component of STEAM must be more highlighted can depend on the type of science learning context. For this, the experts who develop STEAM program need to figure out which component of STEAM should be highlighted or which component of STEAM should be added or made up depending on various type of science learning contexts such as classroom, science center, or natural history museum.

Third, **STEAM program for the natural history museum can include different teaching strategies depending on various type of visitors in ages, gender, or interest.** Two docents employed the inferring strategy for adults and the stamp printing strategy for young kids for 'A' component of STEAM. Young visitors in a family unit interacted with parents to estimate animals' size from the size of footprint and students at secondary school calculated the walking speed of animals from the distance between footprints for 'M'. Appropriate teaching strategy must be adopted by docents or persons who interact with visitors depending on various type of visitors for the effective STEAM program in the natural history museum.

Fourth, **the educator professional development program consisting of theory and practice at the same time are recommended for the successful STEAM program implementation.** Two docents as well as other docents participating in this study appealed for taking training course to be expert in STEAM education. Docents who were involved in this study indicated that they were asked to develop STEAM program and implement it but they were afraid of doing practices since they did not know what to develop and how to implement for STEAM program. Two docents showed very positive reaction in that they took the chance of being expert in STEAM education with the help of researchers and other four docents also responded positively that they became to know what STEAM education was. All of docents in this study hoped that there would be another chance for them to be involved in educator training workshop to be expert in STEAM education, where they could learn theory to be connected to practices.

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