Searching for Science Education in On-Line Resources Provided by Natural History Museums[1)]

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ABSTRACT

The purpose of this study is to explore characteristics of on-line teaching materials on websites of natural history museums, particularly with regard to educational perspectives and the nature of science. The target resources were selected from the websites of the Natural History Museum in London, the Australian Museum in Sydney, the Field Museum of Natural History in Chicago, and the Smithsonian Museum in Washington D.C.. A total of twelve on-line resources from these museums used in this study were selected as representative informal science teaching materials.

For the investigation, this study developed a checklist with a total of nine items that were grounded on mostly reviewing previous literature and articles focusing on educational perspectives of natural history museums and science centers. Exciting and positive results were found in all four museums. The analyses, however, indicated weaknesses as well as strengths in on-line resources regarding their usages as informal science teaching venues.

Key words: natural history museum, on-line teaching material, informal education

I. Prologue

A growing number of educators have perceived and expected that informal institutional settings like natural history museums could play a more active role in science teaching and learning (National Research Council, 1996). Accordingly, there have been researches examining student cognitive and affective gains from experiences at informal settings for 25 years (Melber & Abraham, 2002). Yet most studies at informal settings relate to visitor behavior and time spent at exhibits, while literature regarding learning and instruction from the perspective of educators and the educational programs they provide remain deficient (Tran, 2003).

But Hawkey (2001) tried in-depth analyses of major natural history museums including the Natural History Museum in London where he was on staff. He brought about new perspectives for perceiving natural history museums such as the nature of science, educational perspectives, roles of museums for public education, and progress in research of biodiversity. His target resource of investigation was on-line information provided by natural history museums, while

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1)This work was supported by Korea Research Foundation Grant(KRF-2002-074-BS1534).

presuming that the websites of natural history museums have been seen as potentially excellent vehicles for conveying ideas about life and earth science to a much larger and more diverse audience. Thus Hawkey looked through as many aspects of on-line museums as possible, including mission statements, resources, program information, on-line exhibits, and so on. Consequently, his research met the needs of investigation grounded on a point of view of science educators described in a previous paragraph.

This research, however, was rooted on realizing that Hawkey's work did not present a full range of understanding natural history museums as a venue for informal institutional settings for science education. He analyzed, rather broadly, overall contents presented on the websites without examining details of each categorized resource in his earlier work. Emphasis in this study was specifically put on a category of on-line educational resources that were designed for use in science classes in order to make a better picture of how natural history museums could be involved with school science in the name of informal education. Four major natural history museums were selected for this study: the Natural History Museum in London, the Australian Museum in Sydney, the Field Museum of Natural History in Chicago, and the Smithsonian Museum in Washington D.C.. Most of these museums have one to two million visitors on average, annually.

This study explored the expression of views of the nature of science and educational perspectives on educational resources of selected natural history museum websites. For these analyses, checklists were developed from reviewing literature pertaining to science educators' concerns, and research reports resulted from investigating informal institutional settings.

Ⅱ. Background

1. Usage of On-Line Resources to Reduce Novelty Effect for Better Informal Learning at Museums

Research has already established that learning occurs in informal settings, even with better gains in understanding content knowledge as well as in the cognitive and affective domains (Allen, 1997; Boisvert Slez, 1995; Borun Dritsas, 1997; Falk Dierking, 1997). However, there are also researches to explore some impediments that can weaken its effectiveness. For instance, Falk *et at.*(1978) found that placing children in an extremely unfamiliar setting may cause sufficient stress to block any meaningful learning experience.

Later on, several researchers explored ways of overcoming such problems in the name of 'reducing novelty'. Finson Enochs(1987) reported that teachers can increase the potential for cognitive and affective learning in museums by planning structured activities before and after field trip visits. Also Kubota Olstad (1991) concluded in their report that by reducing the novelty effect, on-task exploratory behavior increasedand greater cognitive learning occurred. Furthermore Anderson and Lucas (1997) reported that year eight students who underwent novelty-reducing pre-orientation to the physical environment of an interactive science museum, and had prior experience visiting the museum, learned more than their counterparts.

Hence this study proposed that employing on-line educational resources in science classes could be a convenientpre-visit activity in order to reduce novelty. Recalling teachers did not specifically prepare students for a visit to a discovery center of natural history and exhibited

formal school behaviors in the informal environment (Cox-Petersen Pfaffinger, 1998), one of the biggest reasons for this will be not enough information regarding museum exhibits, nor materials for pre-visit activity. Of course, such backgrounds push museums to keep developing useful and available resources for use in school science. Thus lots of resources were uploaded on the museum websites. Such on-line materials, however, have not been properly evaluated to be accepted as appropriate learning resources.

2. Natural History Museums and Nature of Science Approach

Natural history museums are in a unique position because of the decades old collections that are the core of their existence and characterized by a high degree of fundamental scientific research. Referring to an exemplary mission statement provided by natural history museums, they used their collections to promote the discovery, understanding, responsible use and enjoyment of the nature. Such understanding directly connects to their educational role. In other words, as Hawkey stated in his study, they generate resources of great use in education to the teacher and students of science. Continuously, more and more resources are produced in electronic format, i.e. on-line (Hawkey, 2001). Their contents have been improved with including visitor information, opening time, entrance fees, and bus routes as well as useful teaching and learning materials and lesson plans sometimes in an interactive form.

Certainly it is accepted that the internet can deliver conventional science educational messages more rapidly, more effectively, and to a much wider audience. We can visit world famous museums at home without paying any fee nor flying out to Europe or North America. In this study, more attention with regard to on-line resources is paid to their potential as a resource for learning in domains of experiencing models of scientific enquiry and the nature of science. We suggested three categories to evaluate the potential of educational resources for science education.

One category consisted of five items based on King' s research. King (1996) developed a set of categories relating to aspects of the nature of science. The rationale for her categories is given below (King, 1996; Hawkey, 2001).

1) Science as a human endeavor: Presenting science as a social and cultural activity, as a human enterprise, may facilitate enhanced access and help to question the often-supposed neutrality of science. 2) Scientists at work: Showing what scientists actually do-processes such as investigation, publication and debate - can contribute to an understanding of the status and validity of scientific knowledge. 3) Scientific knowledge: Stressing scientific ideas as theories or models - rather than as incontrovertible fact or the revelation of truth-leads to a different view of scientific understanding. 4) Doubt and debate: Presenting scientific ideas as the best model so far developed introduces scope for further questioning and reinterpretation of evidence. 5) Opportunities to formulate their own opinions: an exhibition can reflect the social construction of science and encourage students to formulate their own opinions.

The next category is with regard to whether the resource uses are inherently interactive. There should be clear educational objectives which encourage individuals to understand real objects or phenomena through physical exploration which involves choice and initiative. It certainly seems appropriate to expect a website with educational aspirations to incorporate clear learning objectives and a multiplicity of outcomes depending on the visitor's individual

explorations (Hawkey, 2001).

The lastcategory is to examine whether the resources provide an appropriate model of scientific enquiry. It is a critical characteristic of on-line resources when considering their educational role. Formal science curricula include some understanding of its knowledge base (Hawkey, 2001). Recent developments in considering scientific literacy or the public understanding of science have also given increasing emphasis to the processes and practices of science (House of Lords, 2000).

Our research aimed at establishing a rationale of using on-line resources with an emphasis of the nature of science and science educational perspectives. Thus, to fulfill this investigation, this study leans on descriptive data analysis using checklists developed for the examination. In this article we summarize the findings of two such checklists administered to a total of twelve on-line resources from four natural history museums. Finally, we discuss some practical implications of using on-line resources for teachers and the educational staff of museums with a form of an exemplary vignette.

Ⅲ. Methods

1. Selection of Target Resources

The research team decided upon what are the four best exemplary natural history museums in the world. Based on related researches and recommendations from researchers who visited world-famous museums, four museums were chosen. Three educational resources from each of four museums were selected as representative informal science teaching materials. Quite often this type of selection of online materials employs a method of choosing top ranks in the number of visitors of websites. The selection process of the four museums, however, was based on stated reputation by research members of the project titled "Advancing Science Education Through Enhancing Education and Display Function of Informal Education Institutes". Therefore four selected museum sites were used in this study for they are provided and supported by world renowned exemplary natural history museums. The resources titles are as follows:

- **National Museum of Natural History in London(http://www.nhm.ac.kr/)**

NHM-1.Exploring biodiversity - http://internet.nhm.ac.uk/eb/index.shtml
NHM-2.Walking with woodlice - http://www.nhm.ac.uk/interactive/woodlice
NHM.-3 Quest - http://www.nhm.ac.uk/education/quest2/english/index.htm

- **Smithsonian Museum of Natural History in Washington, D.C.(http://www.smithsonian.org/)**

Smithsonian-1. Lewis and Clark as Naturalists - http://www.mnh.si.edu/lewisandclark/
Smithsonian-2.Expedition to Galapagos! - http://www.mnh.si.edu/expeditions/galapagos/
Smithsonian-3.Lewis & Clark, Mapping the West - http://www.edgate.com/lewisandclark/

- **Australian Museum in Sydney (http://austmus.gov.au/)**

Australian-1.Teachers Resources - http://www.austmus.gov.au/teachers_resources/
Australian-2. Fish Student stuff - http://www.austmus.gov.au/fishes/students/index.htm
Australian-3. The human story - http://www.amoline.net.au/school_visits/resources.htm

- **Field Museum in Chicago(http://www.fieldmuseum.org/)**

FM-1.Project E.R.(Environmental Rescue) - http://www.fieldmuseum.org/projecter/
FM-2. The Sue Files - http://www.fieldmuseum.org/thesuefiles/
FM-3. Expeditions @Field Museum - http://www.fieldmuseum.org/expeditions/

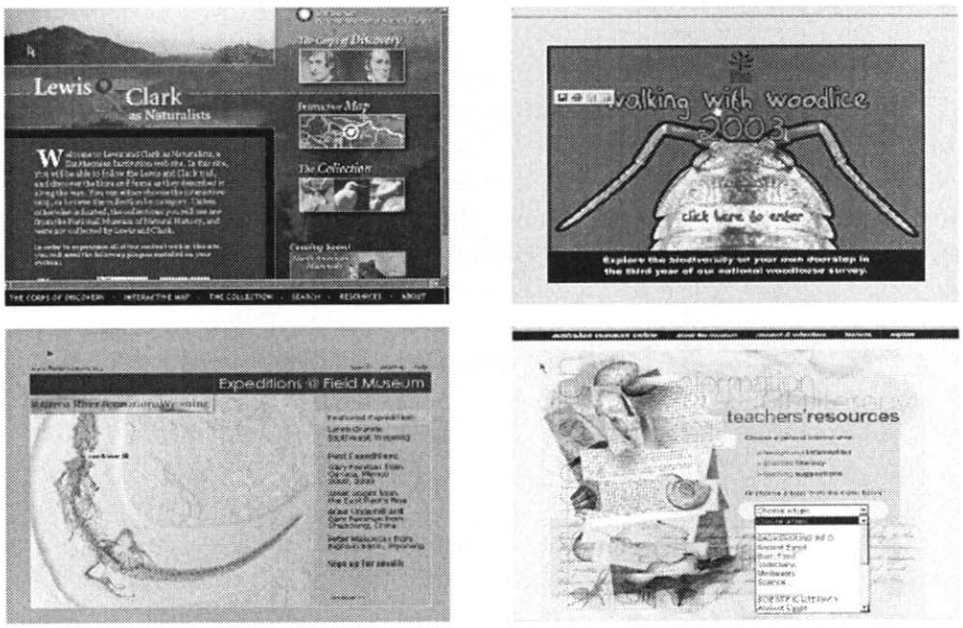

Fig. 1. Four Examples of Each Museum Online-Resource(Up-Left: Smithsonian 1, Up-Right: NHM 2, Down-Left: FM 3, Down-Right: Australian 1)

2. Checklists

A key aspect of this investigation was that the on-line resources shared some common characteristics that allowed them to be incepted into science education. Based on prior research on the characteristics of natural history museums focusing on the nature of science and science education (Hawkey, 2001; King, 1996), nine items in two checklists regarding educational resources were identified as such common characteristics through these literature reviews. One checklist was related to descriptive types of questions focusing on types of resources, interactivity and the purposes. The other consisted of the five items regarding the nature of science and one item focused on scientific enquiry. These checklists were employed to analyze a total of twelve on-line resources. The items were as follows in a format using interrogative adverb:

Checklist 1〉

-What is the type of resources as stated in its websites?
-Is using the resource inherently interactive?
-What were the on-line stated purposes for the resources?

Checklist 2〉

-Does the resource depict science as human endeavor?

-Does the resource depict what scientists do?
-Does the resource mention the nature of scientific knowledge?
-Does the resource include "doubt and debate" in the scientific community?
-Does the resource mention allowing "people's own opinions" in the scientific community?
-Does the material provide an appropriate model of scientific enquiry?

The authors' allocation of particular categories to each resource was based on their experiences as science educators, and was grounded in their literature reviews on informal learning through natural science museums and science centers.

Equally as important, these characteristics were present in enough materials that a valid descriptive analysis was possible. The average of agreement rate pertaining to each checklist item by two researchers was employed for establishing an inter-rater reliability. It was 0.8 and differences between graders could be neglected statistically.

Ⅳ. Findings and Discussions

1. Description of Resources

Types of selected educational resources from four museums were defined in Table 1. The classification of "teaching resources" implicated that the resources are supplementary materials to school curriculum. Also, so are 'activity resources'. The difference between teaching activity and resources is their usages in class. Activity is closer to a unit for student hands-on activity in class. Resources refers to supplementary materials such as reading materials for further and deepened knowledge. Furthermore, a resource titled, 'the human story', in the Australian Museum, and 'Lewis & Clark, Mapping the West', in the Smithsonian Museum, were classified as 'lesson plan', literally. All the educational resources selected for this study, however, can be used in school science. Even though it is true, some resources categorized as 'a lesson plan for direct uses in class' were differentiated in one way or another. In other words, some (of such omit) resources provided clear notions of being used in the classroom, as well as having concrete connections with the existing curriculum and student worksheets with teachers' manuals.

First, they started with the notion of a school science curriculum. Some are incorporated into the following *'Exploring biodiversity is a unique science teaching resource packed with innovative online and offline materials that link to the UK national curricula and A-level courses'*(NHM-1 Exploring biodiversity). *'The lesson plans here are provided as support for teachers that are passing on the national heritage of the time'* (Smithsonian-1, Lewis and Clark as naturalists). Another characteristic is full preparation for school uses. The exemplary model is 'The human Story' of the Australian Museum. This lesson plan comes with lots of materials that are divided into a student activity part, including handouts and worksheets, and a teacher section with supporting materials and in-depth explanations as well as a teacher's guide and learning goals. While most resources on the websites need lots of efforts and work on the part of teachers for use in class or only remain as supplementary information, such a lesson plan as 'The Human Story' is a full version of lesson materials so that it is ready to be adopted in science classes.

A second category for descriptive analysis of on-line resources is 'interactivity' (see Table 1).

Table 1. Descriptive Analyses of On-Line Resources from Four Natural History Museums

	Type of Resources	Is It Interactive?	On-Line Stated Purposes
NHM,U.K.			
1. Exploring biodiversity	Teaching resources	Interactive	Linkage with formal education system
2. Walking with woodlice	Survey activity(unrelated to school curriculum)	Interactive	Public connection with collections
3. Quest	Activity	Interactive	Public connection with collections
Smithsonian, U.S.			
1. Lewis and Clark as Naturalists	Activity resources	Interactive	Only for retention of audience
2. Expedition to Galapagos!	Reading materials	Not Interactive	Public connection with collections
3. Lewis & Clark, Mapping the west	Lesson Plan	Partly Interactive	Linkage with formal education system
Australian Museum			
1. Teachers Resources	Reading materials and some activities	Not Interactive	Public connection with collections
2. Fish-Student stuff	Informative materials	Partly Interactive	Public connection with collections
3. The human story	Lesson plans and teaching activity	Partly Interactive	Linkage with formal education system
Field Museum, U.S.			
1. Proejct E.R.(Environmental Rescue)	Teaching resources	Partly Interactive	Linkage with formal education system
2. The Sue Files	Reading materials and activities	Not Interactive	Only for retention of audience
3. Expeditions @Field Museum	Teaching resources	Interactive	Public connection with collections

Table 2. Checklist for Analyzing On-Line Resources in Terms of Nature of Science

	Science as Human endeavor	What scientists do Knowledge	Nature of scientific	Doubt and debate	Own opinions Enquiry Model	Providing Scientific
NHM,U.K.						
1. Exploring biodiversity	**	**	**	**	*	**
2. Walking with woodlice	**	/	**	/	/	**
3. Quest	**	**	**	*	*	*
Smithsonian, U.S.						
1. Lewis and Clark as naturalists	**	**	/	/	/	**
2. Expedition to Galapagos!	**	**	**	**	*	**
3. Lewis & Clark, Mapping the west	*	*	/	/	/	*
Australian Museum						
1. Teachers Resources	**	**	*	/	/	**
2. Fish-Student stuff	**	**	/	/	/	/
3. the human story	**	**	**	**	**	**
Field Museum, U.S.						
1. Proejct E.R.(Environmental Rescue)	*	*	*	*	*	*
2. The Sue Files	**	**	**	*	*	*
3. Expeditions @Field Museum	*	**	*	/	/	**

*not at all / - not mentioned * - mentioned ** - Clearly mentioned

Although it is important not to simplistically equate museum interactivity with multi-media, an interactive museum exhibit can be readily extended to the virtual domain (Caulton, 1998). Using most on-line resources is inherently interactive, as shown in Table 1, except those categorized as 'reading materials'. Of course some resources marked with 'lesson plan' and 'teaching resources' were partly interactive, which means that the resultsof interactive action of users would not be apparent but indirectly given; for example, Smithsnian-3, Field Museum-1, and Australian Museum-3. There are explicit examples of interactive resources, such as 'Quest' (NHM 3), that allow learners to share findings and ideas rather than providing prompt reaction to the user's responses.

Given the inherently interactive nature of the web as a medium of communication, it is perhaps surprising that there are few examples of empowering learners or even of facilitating dialogue. The increasing practice of such approaches in natural history museums may be expected to have an impact on this.

The last column in Table 1 presented the results of classifying on-line stated purposes of each resource. It examined what were the on-line stated purposes for the resources. Melber Abraham (2002) proposed three key areas in determining the course of natural history museums. This study adopted their three categories into classifying such purposes: firstly, retention of audience which means that on-line resources are able to capture the public's interest and influence their choice of leisure activities; secondly, public connection with collections which are interpreted as natural history museums and are called upon to justify how their collections contribute to overall ecological preservation in today's world; lastly, linkage with formal education system. In this study it was found that most resources were aiming at public connection with collections and linkage with formal education system.

Public connection with collections can be understood to mean that natural history museums have a mandate to not only educate the public on the scientific content of their exhibits, but also on the history behind their collections, policies governing them, and the educational relevancy of said specimens. Further linkage with formal education is grounded on the fact that natural history museums offer experiences that the traditional classroom cannot, providing access to both expertise and actual specimens. More often than not, those two categories are hardly discerned. For example, NHM, U.K.-1stated its purpose as 'It encourages an active learning style where students explore biological concepts through investigation data'. It was classified as linkage with formal education. Yet, this purpose can be allocated as apublic connection with collections. Consequently, the rationale of on-line educational resources was based on their educational role, classified as informal learning.

2. Nature of Science and Scientific Enquiry

In this study, it was seen to be possible to apply an analytical approach to a selection of on-line resources on a selection of natural history museum websites by means of King's category (1996) focusing on the nature of science. Five columns in Table 2 present the results.

Science as a human endeavor. Most resources referred to science as a human endeavor and include scientists' names, photographs, and sometimes even live links to the field. Furthermore these resources often provided elaboration. There are some examples of this. *'Lewis and Clark left an extraordinary record of their quest in the journal writings they kept '(Smithsonian-1)*

'Dr. .Gary Feinman and his team as they continue to uncover what life was like high above the floor of Mexico's valley of Oaxaca' (Field-3) Other sites refer more generically to 'scientists' or include rather more limited biographical information.

What scientists do. Most resources include considerable references to the research activity of their scientists. This might be implicit and this study looked for terms such as investigate, discover, model, describe, identify, experiment, analyze, properties, patterns, relationships or, more rarely, explicit references, such as Hawkey's guide in his prior work (Hawkey, 2001). Such examples are *"identify a question or hypothesis to test,.."*(Field-1), *"scientists rely heavily on information that accompanies each specimen or object within a collection"*(Australian-1) and *"use diagrams, tables, charts and graphs, and identify and explain patterns or relationships in data"*(NHM-1). Especially, NHM-3 included a notion of *"you are a scientist at the museum"*.

Nature of scientific knowledge. While Durant (1992) expressed his concern that much material on websites tends to give the impression of science as the sure and solid mastery of nature, selected resources in this study tended to be rather more deeply incorporated with the nature of scientific ideas. For example, NHM-1 provided the reader with an instruction *"to consider the power and limitations of science in addressing environmental questions"*. Another example is *"scientists still don't know everything about woodlice-this is where you can help"*(NHM-2)

Doubt and debate. Although many resources explore the scientific research process, there is not much evidence of the dynamic interplay between conflicting or competing ideas. Nevertheless it is a quite encouraging result that half of the on-line resources provided positive evidence. For instance, NHM-1 stated *"including the kinds of questions science can and cannot answer, uncertainties in scientific knowledge, and the ethical issues involved"* and Australian-3 clearly mentioned *"although we have done our best to ensure that the information we have provided is accurate and up to date, the minute these activities are printed, new evidence may come to light that will change the story we have presented here"*

Opportunities for audience to formulate their own opinions. The findings in this category are quite similar to the previous one. There are quite a few pieces of evidence indicating formulation of one's own opinions. There are some examples: *"activities deal directly with species and issues that are currently the subjects of considerable debate among the scientific community"*(Australian-3), and *"publish your own ideas and read what other people have said"* (NHM-3).

Providing Inquiry Model The last column in Table 2 was digging into whether the on-line resources provide the appropriate model of scientific enquiry. What was meant by inquiry model is similar to what actual scientists do in their research. For instance, proposing a cook-book type of student activity was not rated as 'inquiry model'. It was found that most resources provided such models. NHM-1 included lines saying things like *"..designed carry out preliminary work and make predictions, where appropriate / to introduce school students and non-specialist adults to biodiversity concepts and measures"*. Other examples "to use the internet to share scientific information and to take part in a nation wide scientific study"(NHM-2), "the human story senior science session involves in-depth investigation of some of the issues"(Australian-3), and *"determinewhether the evidence does or does not support your hypothesis, and present your answer or conclusion in a final report that will persuade others"*(Field-2). As a further example, the human story(Australian-3) was started with intriguing situation where students can examine several different skulls and bones. Differentiating these skulls and bones leads them to ask

questions related to human evolution. Students start to be engaged into their own inquiry.

V. Epilogue

The findings presented in this paper reflect attempts to develop more consistent and more objective approaches to the analysis and evaluation of the practice of on-line resources in terms of science education and the nature of science. This study tried to avoid the crude scoring presented. Of course, the comparisons among selected museums were, if any, not our intention nor interest. Previously Hawkey (2001) applied King's category (1996) and reported his own analysis. Based on his report and findings, he asserted that the potential of the internet for museums to truly share their passion for science is clear.

Through investigating this study, on-line educational resources have been seen to possess such potential in terms of the nature of science and cooperation of formal educational systems. It is certain that natural history museum websites provide a resource engaged in science education, one way or the other. More efforts by means of cooperation with science educators make those resources more useful to provide an apposite model of scientific enquiry. In conclusion, we suggest that future efforts to investigate learning in museums should involve collaborative action researches with school teachers as well as science educators. Such researches will occur in science classes with an emphasis on how on-line resources can be used for better understanding of how students construct their own knowledge through experiencing the model of scientific enquiry as well as for reducing novelty in a form of pre-visit activity for better informal learning effects.

Another usage of results here would be related to developing online materials for the natural history museums in Korea. Currently, most information provided by Korean museums is general information including opening hours and admission rates. Some of museums present pictures of specimen from museum exhibits. However it is hardly found that such museums develop and share online materials for teaching and learning purposes. Teachers and students could not find teaching resources in museum web sites even though they are interested in pre-visit activities or post-visit activities with using given materials by natural history museums. Rarely in our museum websites did we ever find the notion of education purposes or mention of school curricula as showing their concern and interest about their role as informal education institutes. Before developing online materials, museum staff should discuss how to make the public's visits more meaningful. Also, they need to review science education researches classified as informal learning study. Literally, natural history museums' efforts to become more meaningful informal education institutes will not even begin until such discussion is done.

This research is in the beginning stage. It was searching for the possibilities of science education involvement in informal educational institutes like natural history museums. In the view point of science educators who mostly have their works focused on formal education, the informal education institutes have been interpreted and examined. Of course one could argue that "informal" needs its own research method and scope instead of adopting a 'formal' scope. Nevertheless more research in the future needs to look into 'informal learning situation' by means of previously developed tools and research ideals for formal learning situation because both formal and informal should work on the same goal of 'better learning and better citizens'. For instance, pre-visit and post-visit activities can be investigated in terms of better student

achievement and attitude. One of the purposes of this study is to encourage all other tries and attempts to adopt and employ well developed science education research approaches focusing on formal education in order to investigate the potential of formal and informal education working together.

Lastly, a vignette is presented to illustrate using on-line resources on natural science museum websites in an imaginary school science class. To provide a practical figure of how on-line resources can be adopted in class, we developed this vignette.

Vignette: The Example of Using On-Line Resources

Before the tour experience focusing on human evolution would begin, students would gather in class. After a brief introduction of a teacher, students would be invited to explore the resources and on-line exhibits while considering a guiding question such as "How have humans evolved?" or "How are these various human skulls and chimpanzee alike?" or "Were chimpanzee our ancestors?" These questions refer to big ideas and require studentsto recall personal experiences and observations.

After this short orientation period, students would regroup with a teacher. Students would be encouraged to talk about what they saw similarities, and differences, leading to a brief discussion of human skull differences and the importance of adaptations and connections. Only a minimum amount of jargon such as dental arcade and muzzle angles would be introduced or clarified.

After this brief discussion, students would be introduced to their primary task for the exploration through the websites: an in-depth examination of human evolution. The teacher would divide the class into five predetermined groups of 4-6 students and each group chooses one topic for an investigation. Each student group is given a learning tote bag that contains data cards, marking pens, an information sheet to show useful web-sites addresses, and several touchable specimens related to several human ancestors. These touchable items might include a skull or jaw replica, a fur, or replicas related to the topic of investigation.

Browsing the websites, each group would find a solution for their own questions. Especially, comparison with pictures on the websites and skull replicas would help them get closer to their own answer. Teachers would ask several prompting questions to help students think more critically about the items they touched. After sharing ideas about the skulls and accessible information, a teacher would distribute the data cards, one for each pair of students. Students would be encouraged to respond to the questions on the card, with minimal guidance from the teacher. The questions are based on the teacher resources given by the museum such as Australian Museums, and paraphrased and reorganized by teachers. Surely these questions are open-ended and linked to the formal science content standards.

Students would reach their own solutions after 20-30 minute-investigation. Their original ideas would be shared with other groups of students. For the in-depth sharing and discussion, a teacher sets each two groups as a pair. Each pair exchanges their question cards and has a time for grasping main idea of each other's question and searching for a tentative solution. It will take only about 15 minutes. After that, each pair of groups would share their solutions and discuss possibly better ideas of solutions as well as assessing each other's solution. After all this procedure, a teacher distributes challenge cards to each group. This challenge card includes an even more difficult and complicated question. More often than not, this question is quite

broad and comprehensive inherently to make students think of human evolution and changing environments. This question will not be solved nor discussed until students visit a nearby museum where they can find more concrete evidence for their own creative solutions.

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