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Research Report

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Currently, I am conducting two separate studies about students who visit Science Education Center (SEC) at Laser Interferometer Gravitational-wave Observatory (LIGO) Livingston as their school field trip. The first study is "Students' learning at science exhibits at LIGO SEC" and the second study is "Students' attitudes and understanding about science in their field trip to a science center."

The first study was conducted by Exhibit Surveys with approximately 1,000 students (5^{th} – 9^{th} grades) who spent freely at the SEC's exhibit hall for 30-50 mins at their field trip in spring 2013. Each student was asked to respond for two exhibits randomly among 10 exhibits that were selected for the study. It took about 10 mins to complete the survey. The survey was done by written response using pencil-papers considering the students' age and the environment. Excel filing for the Exhibit Survey has been completed for all students. Open-codings have been completed as well. But the codings need to be improved for further details and for more accuracy.

The second study was conducted by pre and post survey with approximately 1,000 students (5^{th} – 9^{th} grades) who visited LIGO SEC for their field trip in spring 2013, and additional data with 370 students (9^{th}/10^{th} grades) were collected in spring 2014. Students were asked to respond to pre-survey before the field trip and to post-survey after the field trip at school. The pre/post survey consist of Likert-type questions asking about their interest and attitudes toward science and open-ended questions asking about their conceptions about science and understanding of LIGO mission and the fundamental scientific concepts of LIGO. The pre/post survey was also done by written response using pencil-papers. Excel filing needs to be complete for the newly collected data in spring 2014. Analysis was conducted for the part of spring 2013 data. Once the excel filing is complete with the new data set, analysis will be conducted again for the combined data. The findings from the spring 2013 data were presented at the AAS 224th meeting (Jun. 5, 2014, Boston, MA).

= Contents =

1. Research 1: Students' Learning of Science Exhibits at LIGO Science Education Center

1.1. Current status of studies

► Goal: To investigate students' understanding/difficulties/or misconceptions at science exhibits.

- What do students learn from science exhibits?
- Any differences observed from different types of exhibits?
- Any misconceptions are created from science exhibits?

► Instrument: Exhibit Survey (10 exhibits)

► Data Collection and Process Status

Schools	Grade	Date of Survey (Spring 2013)	Number of Ss visiting LIGO	Data Process (Excel filing†)
School A	5th grade	Feb. 6, 7, 19, 20	400	Completed
School B	6th grade	Feb. 28, Mar. 5, 6, 7	280	Completed
School C	6th grade	Apr. 17, May 3	90	Completed
School D	9th grade	Apr. 16	40	Completed
School E	6th grade	May 7, 8, 9 10	310	Completed

† : As the survey was conducted in written responses on papers, their responses need to be transferred into computer files for analysis.

► The number of participated students on each exhibit survey and exhibit characteristics

Category	Characteristics	Exhibits	Note	Number of students on exhibit survey
Type A: Fixed Exhibit	The exhibit is fixed and it doesn't need any manipulation to start. Students observe or experience the exhibit.	a. Touch the Spring	(Static)	194
		b. Hot Spot	(Static)	186
Type B: Demonstration with a button manipulation	There is a simple button or a knob that changes one or two variables. It is focused on observation of what the exhibit demonstrates.	c. Doppler Effect	(Sound, Motion)	194
		d. Resonator	(Motion)	190
Type C: Experiment with closed purpose	Fixed variables. There is a specific goal in manipulating the exhibit. For example: shooting the balls into cups (Gravity's Rainbow), or controlling the strength of the vibration to make a certain shape (Visible Vibration).	e. Gravity's Rainbow	(Dynamic)	197
		f. Visible Vibration	(Motion)	191
Type D: Experiment with open purpose	Open variables. Specific goal is not designated in the exhibit. Students manipulate the exhibit in many creative ways. For example: arranging filters/mirrors/lenses in various ways (Light Island), or plucking the strings in various ways to play music (Oscylinderscope).	g. Light Island	(Static)	193
		h. Oscylinderscope	(Sound, Motion)	188
Type E: Experiment with open purpose and easy Analogy	Open variables, but limited number. The exhibits present easy analogy of scientific concepts.	i. Gravity Well	(Dynamic)	179
		j. Giant Slinky	(Dynamic)	177

► Analysis Status

1) Likert-type & multiple-choice questions:

   Descriptive statistics for the data have been completed.

   Looking to understand the meanings of the results.

2) Open-ended responses:

   Had set up two types of codings for open-ended responses. One is conceptual-coding that is relevant to a target scientific concept that each exhibit represents. The other is overarching-coding that embraces for all exhibits. Currently working on codings.

   i. Conceptual-Coding:

Exhibit	Examples of conceptual-coding
a. Touch the Spring	Reflection, illusion, light, mirror, shadow, invisible, etc.
b. Hot Spot	Heat, heat waves, hot, reflection, mirror, light rays, etc.
c. Doppler Effect	Motion, radiation, speed of sound, sound waves, high/low pitches, siren, whistle, weather channel, etc.
d. Resonator	Resonance, falling bridge, sound, wave movement, vibration, etc.
e. Gravity’s Rainbow	Force, power, acceleration, gravitational pull, pulling down objects, height, angle, etc.
f. Visible Vibration	Sand reaction, pattern, vibration, frequency, etc.
g. Light Island	Mirror, rainbow, light travels, prism, color combination, light reflection, refraction, etc.
h. Oscylinderscope	Vibration waves, sound waves, gravitational waves, energy travels, guitar strings, etc.
i. Gravity Well	Gravity, gravity pull, planets, orbit, rolling balls, circle, etc.
j. Giant Slinky	Waves, gravitational waves, sound traveling, movement, energy, vibration, light, etc.

ii. Overarching-coding (It needs some more clarification.)

A. Operation	simple description about operation, usually from the label
Aa	ex) try to touch, can't touch, invisible spring, etc.
(Ab)	ex) illusion, hologram, trick
B. Scientific / Observation	basic scientific concept, basic observation, may often from the label, ex) light, reflection, mirror, etc.
C. Higher Understanding	higher scientific concept, understanding, higher observation that is not described in the label
D. Misconception	Not-related concept that the exhibit represents or is intended
E. Attitude	presenting their feeling or attitude to science, ex) science is fun, it is difficult to understand, what you see is not always real, etc.
F. Other	Ones that do not fall into the above categories

3) Examples of Analysis Result

■ Touch the Spring

(for a larger image, please see the attached pdf file: ConceptMap_A.TouchtheSpring.pdf)

The word inside the oval indicates the *concept* that the students responded. The number inside the oval indicates the number of students who responded the word.

The arrow indicates the flow from *higher concept* to *lower concept.*

“ ” This indicates a quote from students’ responses.

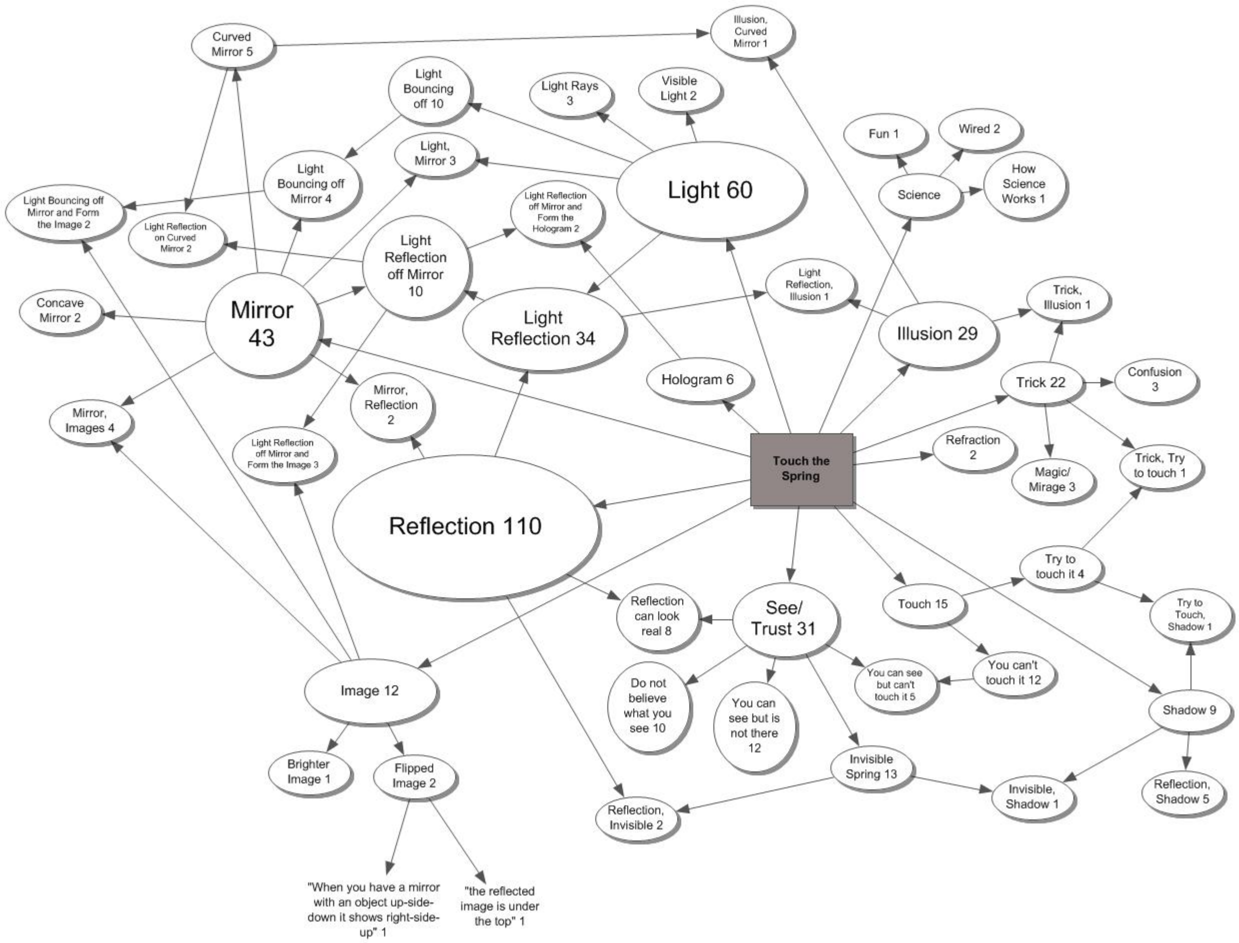
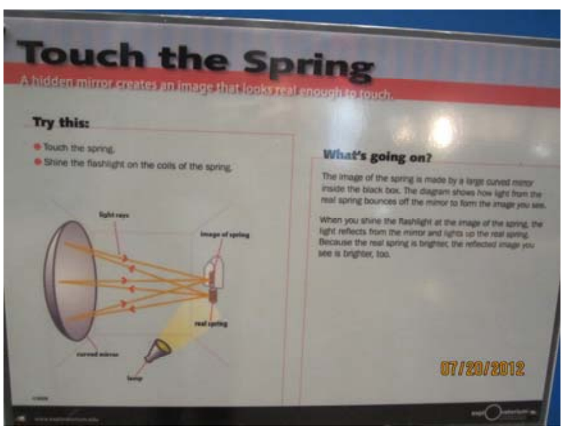


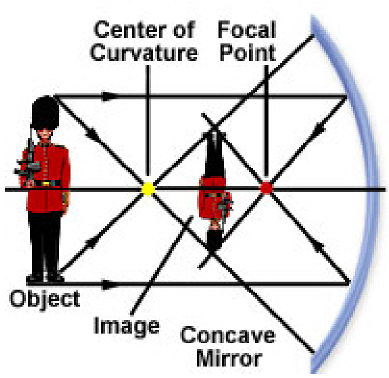
Figure 1. Concept Map: Students' understanding of the exhibit, Touch the Spring (total 194 students)

Among 194 students who responded for the "Touch the Spring" exhibit survey, majority (110 students) mentioned *Reflection.* The next popular concept words were *Light* with 60 students and *mirror* with 43 students. The next was *Light Reflection* with 34 students. Some others responded *Trick* (22 students) or *Illusion* (29 students). There were also students who responded somewhat abstract conception such as *Do not believe what you see* (10 students). Only two students described somewhat higher level of their observation about the exhibit: "the reflected image is under the top" (B2a11), and "When you have a mirror with an object up-side-down it shows right-side-up" (A2a07).

Suggestion: While majority students mentioned *reflection*, it is quite a broad concept. The exhibit label explains the principle of this exhibit with the image as below. However, the image is not clear to show that the reflected image is flipped from an original object. With more cleared image and a modified object (not using the symmetric object), this exhibit would be able to pursue its goal for more students to recognize that the reflected image by a concave mirror is up-side-down from an original object. Any small structures, such as a house or a tree using LEGO, that are not symmetric between up and down would be a good object to use instead of the spring.



Current explanation for Touch the Spring



Suggested Object: Use an object such as the one like left so that the up and the down can be distinguished.

■ Doppler Effect

(for a larger image, please see the attached pdf file: ConceptMap_C.DopplerEffect.pdf)

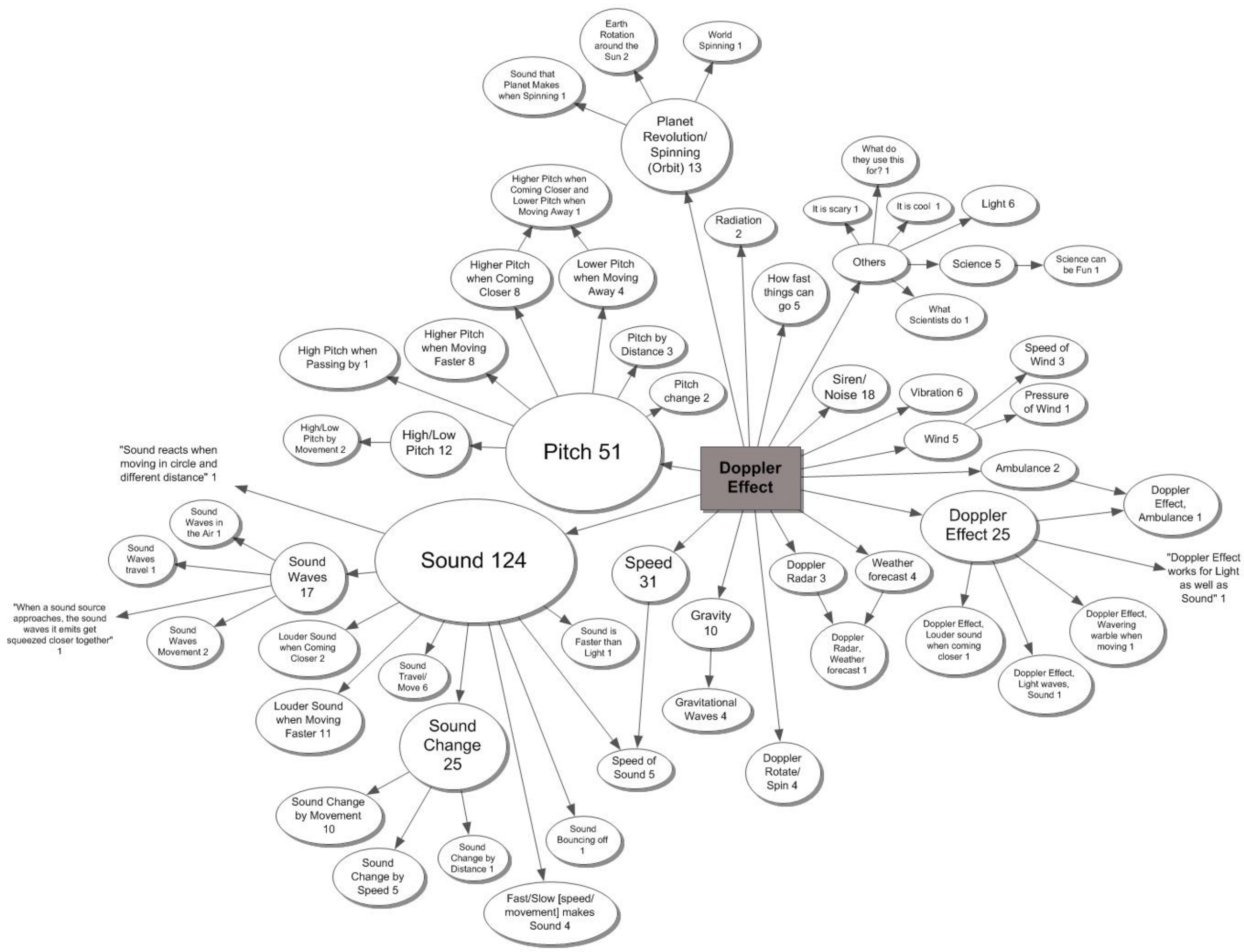


Figure 2. Concept Map: Students' understanding of the exhibit, Doppler Effect (total 194 students)

Among 194 students who responded for the "Doppler Effect" exhibit survey, majority (124 students) mentioned *Sound.* The next popular concept words were *Pitch* with 51 students and *Speed* with 31 students. Some students simply mentioned *Doppler effect* without further explanation. Most students recognized different sound or different pitch that the exhibit is intended to present by the movement of the source, but their responses were somewhat broad such as simply, different *pitch, high/low pitch*, or different *sound*.

A few students described their observation correctly such as *higher pitch when coming closer* (8 students) or *lower pitch when moving away* (4 students). Only one student mentioned the mechanism of Doppler Effect correctly, "When a sound source approaches the sound waves it emits get squeezed closer together." Rather several misconceptions were found from the students' responses. Due to the design of the exhibit that the source is circling around, a few students thought that it represented *Planet Revolution or Spinning* (13 students). One student thought that the exhibit presents *Sound that planet makes when spinning*, and two students thought that it is *Earth rotation around the sun*. Some others thought it represents a *Weathercock* (4 students) or one for *Wind* (5 students).

Suggestion: While majority recognized different sound or different pitch at this exhibit, their responses were very general. In fact, there were not many students who observed correctly how the pitch gets different by the movement of the source or who understood the reason for the difference. Moreover this exhibit even creates some misconceptions that it was not intended to (ex. Planet revolution, weathercock, or wind). I would suggest this exhibit to be in a straight line from a visitor instead of this spinning shape. This exhibit may use an ambulance toy following with a wave shape string. As the ambulance moves either going away or coming closer the wave string may change its shape to be either loosen or squeezed, with the sound of either lower pitch or higher pitch. That way, the exhibit may be able to clearly present the behind mechanism of Doppler Effect.

1.2. Research Paper Outline

The below is a short draft of a paper with previous analysis findings. The final paper will be similar to its outlines but will be added some more literature reviews, detailed methods, and updated findings. Currently, open-codings have been completed for each exhibit with all collected data and I'm working on developing the coding schemes with more details and for more accuracy.

Students' Learning at Science Exhibits of Light, Waves, and Gravity

1. Introduction

This paper reports on the current findings of our study about students' understandings of science exhibits at a federally funded science center in the southern United States. Science centers and museums have as their primary purpose the education of students and other visitors, however they also seek to entertain them. It is generally believed that experiences at science centers increase students' interest in science and motivate them to study science. Although many researchers agree with this positive perspective about the affective impacts of science centers and museums (e.g., Finson & Enochs, 1987; Salmi, 1991), there have been some questions about how much visitors actually learn about science concepts during their visits. Therefore, educators have made efforts to understand how to maximize student learning at science museums. For example, some emphasize the importance of pre- or post-visit activities at school that connect to a field-trip to science museums (Gennaro, 1981), some argue the relevance of novelty to students' learning and behavior at science museums (Kubota & Olstad 1991), or some report the different impacts on student learning by the different degree of freedom given at science museums (Bamberger & Tal, 2007). Other researchers have focused on investigating the influence of different types of science exhibits on learning (Boisvert & Slez, 1995; Sandifer, 2003). Studies about science exhibits, however, have primarily focused on the holding power or the degree of attraction of the exhibits in order to better provide the most effective ways to set up the exhibits in the restricted space of the centers, rather than uncovering their educative values (e.g., Gilbert, 1995).

Science museums are filled with interesting exhibits, however, most visitors stay a short time at each exhibit and then quickly move on (Naqvy, Venugopal, Falk & Dierking 1991). When students interact freely with exhibits, they behave like other visitors and spend little time at exhibits, sometimes only glancing at them. Clearly this limits their opportunity to learn from the exhibits (Sandifer, 2003). In this free-choice type of exploration, what do students learn from science exhibits? Do students recognize the scientific concepts that the exhibits are intended for? Are there risks that the exhibits may lead students to a misconception? If there are any, how can exhibits be improved to increase science learning? The purpose of this study was to seek answers to these questions and to contribute to the literature about the educative value of science exhibits.

2. Design and Procedures

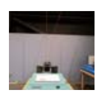
2.1. Setting

This study was conducted at a science education center (SEC) at a US national laboratory. The education center has over 40 hands-on exhibits that are related to the science of the laboratory such as light, gravity, and waves. The education center provides students and teachers with field trip programs in which they tour the laboratory facilities and explore the science exhibits. The SEC field trip programs are 4-hours long and include a video of the laboratory and its mission, a tour of the facility, demonstrations by the staff, a classroom activity, free-choice exploration of the hands-on exhibits, and lunchtime. Students are usually allotted 30-50 minutes for the exhibits

2.2. Participants and Data Collection

About 1,000 elementary and middle school students (5^{th} – 9^{th}) from five different schools in the southern US, who visited the SEC in school field trips in Spring 2013, took part in the study. Data were collected using a written survey for ten different exhibits. The survey form was two-sided, with each side asking ten questions about one exhibit. Therefore, there were five different sets of surveys. The survey forms were randomly distributed to students as they entered the exhibit hall at the beginning of their exhibit exploration time. Students were asked to respond to one set of the survey for two exhibits while they freely explored them. They typically spent about ten minutes to complete the survey.

2.3. Exhibits: The below ten science exhibits were examined in this study:

A: Touch the Spring 	B: Hot Spot 	C: Doppler Effect 	D: Resonator 	E: Gravity's Rainbow 
F: Visible Vibration 	G: Light Island 	H: Oscylinderscope 	I: Gravity Well 	J: Giant Slinky 

2.4. Analysis

Students' written responses on the survey forms were digitized for analysis. Responses to multiple-choice questions were analyzed with descriptive statistics. Open-ended responses were categorized into similar themes and the frequencies were counted. Diagrams were constructed for each exhibit that presents students' conceptions/misconceptions about the exhibit.

3. Findings

Students were asked to answer how much they enjoyed the exhibit and how easy it was to understand what to do at the exhibit (Figure 1). They thought that Gravity Well (I) and Giant Slinky (J) were very enjoyable and easy to understand what to do with it. On the other hand, Light Island (G) and Resonator (D) were thought less fun and were difficult to understand what to do.

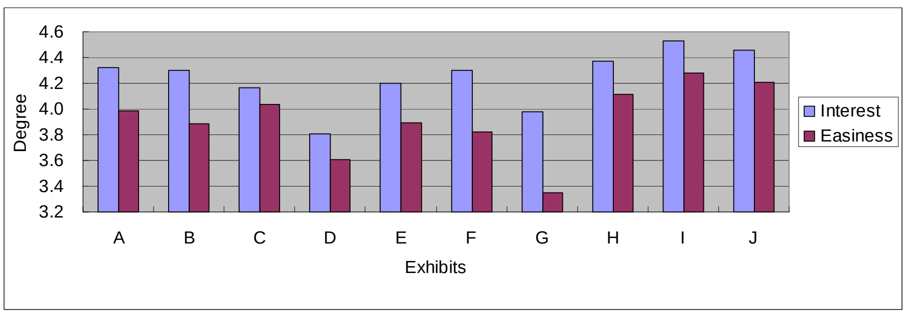


Figure 1. Students' perceptions of their interest and ease at each exhibit

(The data is from all participated students and each exhibit has approximately 200 students responded.)

In the following we present some results about the understanding of the exhibits by students from one of the schools. Each exhibit has approximately 50-70 students responded. We are currently analyzing the rest of the data and will present it at the NARST meeting. Due to a space limit in this proposal, we present our findings from four of the exhibits and only one diagram (see Figure 2).

3.1. Doppler Effect: Demonstration with Simple Manipulation

The Doppler Effect exhibit is operated with a starting button and a knob that changes the speed. When the exhibit is started, a rod spins around the center, and a sound source at the end of the rod makes sound. As it spins, it makes a higher pitch sound when it comes closer to a visitor and lower pitch sound when it goes further away. There is an explanation about the concept of Doppler Effect with a photograph of an ambulance on its exhibit sign. At this exhibit, many students recognized that this exhibit represents *the change of the sound, high pitch and low pitch*, or *sound waves*. A few students gave an accurate description of the phenomenon, for example, "*high pitch when coming close*", or gave a scientific explanation of the Doppler Effect, for example, "*when a sound source approaches, the sound waves that it emits get squeezed close together*." On the other hand, this exhibit misled 9 students who thought it was a weather vane or the spinning of a planet. There were also 7 other students who simply described that this exhibit made noise, whistle, or siren.

3.2. Gravity's Rainbow: Experiment with Closed Purpose and Closed Variables

In Gravity's Rainbow visitors are expected to manipulate the exhibit so that balls roll off of a ramp and land in cups on the floor. Students can change the position of the cups as well as the tilt of the ramp. The positions where each ball would fall are marked on the floor for the cases of when the balls are launched with the largest or smallest tilt.

Figure 2 represents students' conceptions of the Gravity's Rainbow exhibit. In the figure, their conceptions are presented with either an oval when it is related to the scientific concepts that the exhibit is intended (although it is not scientifically correct), or rounded rectangle when it is not related to its scientific concepts. The numbers in the diagrams present the number of students who mentioned it. Many students brought up scientifically relevant concepts, such as *gravity, gravitational pull, effect of gravity, acceleration, pulling down objects,* etc. A few students described what they observed, "*when it's higher it goes further distance, and when it's lower it goes shorter distance*", or showed sound reasoning, "*higher object goes faster," or* "*when gravity has more time to pull on it has more acceleration*."

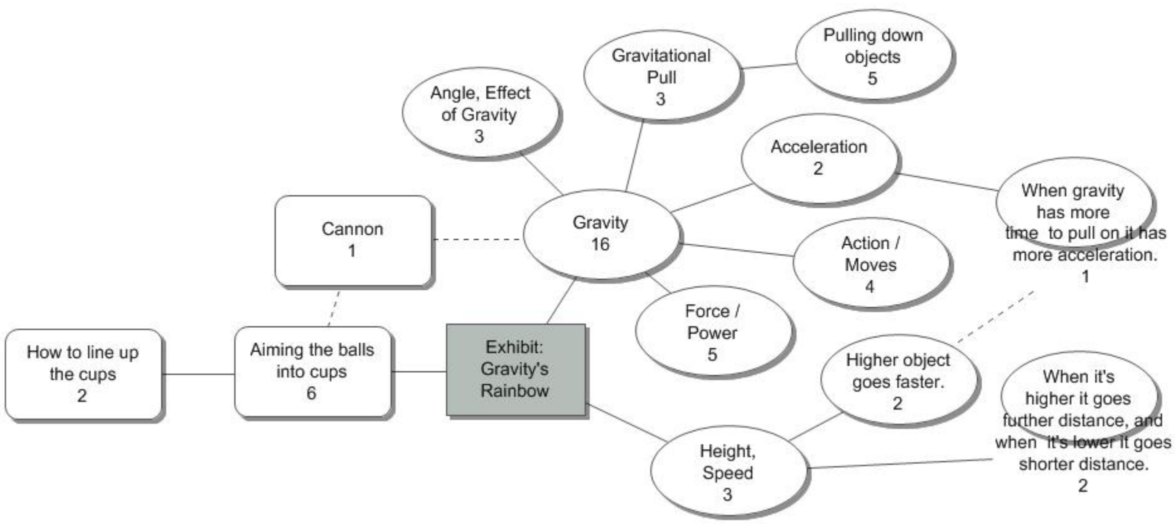


Figure 2. Students' conceptions about Gravity's Rainbow

3.3. Gravity Well: Experiment with Closed Purpose and Open Variable

Gravity Well is an exhibit in which balls spin around a funnel and down a hole. Some variant of it is common in science centers and museums. Students put a ball anywhere on the funnel and watch how it spins around until it ends up in the hole. Students can manipulate it in various ways. For example, they can change its initial speed or direction, or they can make balls crash into one another. At the Gravity Well exhibit most students brought up scientifically related concepts, such as *gravity, gravity pull, gravity force*, etc. Many students recognized the analogy of this exhibit, for example, "*planet orbits the sun*." Some students showed reasoning, yet misconceptions, such as, "more mass takes longer to go around", "heavier objects go down slower," or "smaller objects move faster than bigger ones." And there were two students who thought that the pulling is caused by magnets.

3.4. Light Island: Experiment with Open Purpose and Open Variables

The Light Island exhibit provides visitors with various lenses (convex/concave/prism), mirrors (curved/flat), and filters and single and multiple beams of light on a table. There are explanations about what each object does to light on the exhibit sign. The specific goal is not made explicit in this exhibit. The students manipulated the exhibit materials in many creative ways. Although students' responses to this exhibit were that it was difficult and not very interesting, most students seemed to recognize what this exhibit was intended to show. They brought up scientifically related concepts such as, *light*, *light bending*, *light splitting*, *prism and rainbow*, *light reflection*, *light refraction*, *light that is blocked by an opaque object*, *color or color combination of light*. When students responded that this exhibit was difficult to understand, it may not mean that its scientific concepts are difficult. Rather, its scientific concept is simple and familiar to them. But because there are too many variables (different kinds of mirrors, lenses, filters, where to set them up on table, and single or multiple beam of light) at the exhibit, it is not clear for many students what they are supposed to do with them. It was noticeable that no one mentioned how light reacted to one of the objects, except three students who mentioned the prism and a rainbow. It may be because of the way the exhibit was designed, rather than the scientific concepts, that students may have felt it to be difficult and lost interest in it.

4. Discussion / Contribution

Students typically spend only a few hours at science museums that have many exhibits. If an exhibit's *cognitive overload* (Hedge, 1995) is high, students can lose interest and move on to another exhibit. For example, Light Island is designed with an open purpose that allows visitors play with various objects (variables) in many creative ways. To recognize the outcomes clearly, however, students would need to spend quite a lot of time with guidance from a knowledgeable docent. This type of design may be more appropriate in a classroom setting in which a certain amount of time is allotted and guidance can be given. With the current design in a science museum, visitors may easily lose their interest and go to other exhibits that have more *immediate apprehendability* (Allen, 2004). If science museums and centers want to have exhibits that require visitors to delve into them deeply, they need to have some ways to both keep them involved and provide docents who can guide and scaffold learning.

It may also be necessary to limit the number of variables at an exhibit so that students manipulate them one by one. This could lead to an increase in conceptual learning. It is also important that the purpose of an exhibit and the values/range of its variables are clearly given and easily recognizable. Gravity's Rainbow has a clear goal to make balls go into the cups. The tilt of the ramp can be changed, but its largest and lowest values are marked, so students could easily recognize its limit. The starting positions of the balls are also given on the ramp. This clear setup allowed students to better understand what the exhibit represented, as can be seen in this quote from a student, "*when it's higher it goes further distance, and when it's lower it goes shorter distance.*" As a result some students demonstrated deeper reasoning about it, as seen in these quotations, "*higher object goes faster,*" or "*when gravity has more time to pull on it has more acceleration*."

It appears that whether the purpose of the exhibit is made explicit or not and whether the values or range of variables is clearly given or not seem to affect students' learning of science in free-choice exploration of exhibits. We expect to identify the relationship between exhibit design and student learning as we continue to analyze our data. We believe this study will contribute to the literature of student learning at science museums, especially at free-choice exploration of science exhibits. Science museum educators and exhibit designers would find this study interesting, as well as science educators interested in how students learn from the manipulation of physical models.

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2. Research 2: Students' Attitudes and Understandings about Science in their Field Trip to a Science Center

2.1. Current Status of Studies

► Goal: To investigate students' attitudes about science and their understanding of the LIGO science

- Is there any difference in their attitudes toward science/scientists by field trip to LIGO?
- What do students learn from the field trip to LIGO center (in regard to the scientific concepts and LIGO project)?
- What are students' understandings about LIGO science?

► Instrument: Pre-survey before visiting the LIGO and Post-survey after the visit

► Data Collection and Process Status

Schools	Grade	Date of Field Trip Spring 2013	Number of Ss visiting LIGO	Number of students who were matched between pre and post	Data Process (Excel filing)
School A	5th grade	Feb. 6, 7, 19, 20	400	Excel filing almost complete	
School B	6th grade	Feb. 28, Mar. 5, 6, 7	280	**105**	Completed
School C	6th grade	Apr. 17, May 3	90	**74**	Completed
School D	9th grade	Apr. 16	40	**36**	Completed
School E	6th grade	May 7, 8, 9 10	310	**195**	Completed

In Spring 2014, additional data were collected.

Schools	Grade	Date of Field Trip Spring 2014	Number of Ss visiting LIGO	Data Process (Excel filing)
School F	9^{th}	Feb. 20, 25	100	-
School G	9^{th}, 10^{th}	Feb. 21	90	-
School H	9^{th}	Apr. 2	45	-
School I	9^{th}	Apr. 10	45	-
School J	9^{th}	May 7	90	-

► Analysis Status

As the new data set has not been completed with excel filing, the current analysis has been conducted with the data of School B, C, D, and E.

In the past, I could not find an interesting difference on the Likert-type questions (asking of their attitudes about science and scientists) between the students who had been to LIGO previously and the ones who came LIGO for the first time at this field trip by the simple indication of either yes (had been to LIGO before) or no (had never been to before). (see Prepost2013 report). After I tried several different statistical tests, I discovered interesting and meaningful results from the data of Likert-type questions. One of the tests was regression.

1) Regression

Here, I present one exemplary result from regression.

DV: the degree of post-interest (interest about science after the field trip, range 1-7)

IV: grade, number of previous visits to LIGO, number of previous visits to science museums (not including LIGO), the degree of pre-interest (interest about science before the field trip, range 1-7)

Descriptive Statistics			
	Mean	Std. Deviation	N
post_interest	5.359	1.2127	400
grade	6.27	.860	400
num_visit_LIGO	.53	.725	400
num_visit_ScienceMuseum	1.10	1.179	400
pre_interest	5.118	1.2768	400

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.653(a)	.426	.420	.9236	.426	73.225	4	395	.000
a Predictors: (Constant), pre_interest, grade, num_visit_ScienceMuseum, num_visit_LIGO									

ANOVA(b)						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	249.840	4	62.460	73.225	.000(a)
	Residual	336.929	395	.853		
	Total	586.769	399			
a Predictors: (Constant), pre_interest, grade, num_visit_ScienceMuseum, num_visit_LIGO						
b Dependent Variable: post_interest						

Coefficients(a)														
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	2.104	.418		5.029	.000	1.281	2.926					
	grade	.018	.056	.013	.318	.751	-.092	.127	-.035	.016	.012	.929	1.0

												76
	num_visit_LIGO	-.120	.066	-.072	-1.823	.069	-.250	.009	.006	-.091	-.069	.932	1.072
	num_visit_ScienceMuseum	.038	.040	.036	.933	.351	-.042	.117	.127	.047	.036	.952	1.051
	pre_interest	.619	.037	.652	16.778	**.000**	.546	.691	.648	.645	.640	.964	1.037
a Dependent Variable: post_interest													

Collinearity Diagnostics(a)								
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	grade	num_visit_LIGO	num_visit_ScienceMuseum	pre_interest
1	1	3.921	1.000	.00	.00	.02	.02	.00
	2	.576	2.609	.00	.00	.92	.02	.00
	3	.451	2.947	.00	.00	.00	.93	.01
	4	.044	9.443	.02	.10	.02	.02	.87
	5	.007	23.001	.98	.90	.05	.02	.12
a Dependent Variable: post_interest								

According to the regression result, two equations can be written.

i. Raw Equation:

(Post-Interest) = **2.104** + 0.18*(Grade) + (-0.12)*(number of previous visits to LIGO) + 0.038*(number of previous visits to Science Museums) + **0.619*(Pre-Interest)**

ii. Standardized Equation:

(Post-Interest) = 0.13*(Grade) + (-0.072)*(number of previous visits to LIGO) + 0.036*(number of previous visits to Science Museums) + **0.652*(Pre-Interest)**

While the regression equations show the relationship between the variables, the coefficients of IDs are very small and the correlation values are not significant except for pre-interest. This does not show much information about the students' attitudes and interest to science. To better understand their attitudes about science and scientists with the Likert-type question data, it needed a different test.

2) Correlation between Variables

I obtained Pearson's correlation alpha-values for each variables and Likert-type questions to understand the relationship between variables and the responses to the Likert-type questions. The results are shown in below.

Correlation results total 410 6th grade: 374 9th grade: 36		Number visit LIGO	Number visit Science Museum	Pre Interest	Post Interest	Post-Pre Interest
Number of visit to LIGO before the field trip	Pearson Correlation	1	.105(*)	.110(*)	-.006	-.138(**)
	Sig. (2-tailed)		.035	.027	.898	.006
	N	406	404	402	406	402
Number of visit to Science Museum before the field trip	Pearson Correlation	.105(*)	1	.161(**)	.132(**)	-.043
	Sig. (2-tailed)	.035		.001	.008	.388
	N	404	407	403	407	403
Pre Interest	Pearson Correlation	.110(*)	.161(**)	1	.638(**)	-.484(**)
	Sig. (2-tailed)	.027	.001		.000	.000
	N	402	403	406	406	406
Post Interest	Pearson Correlation	-.006	.132(**)	.638(**)	1	.364(**)
	Sig. (2-tailed)	.898	.008	.000		.000
	N	406	407	406	410	406
Post – Pre Interest	Pearson Correlation	-.138(**)	-.043	-.484(**)	.364(**)	1
	Sig. (2-tailed)	.006	.388	.000	.000	
	N	402	403	406	406	406
diff_Q4.01 "Science is fun"	Pearson Correlation	-.117(*)	-.075	-.181(**)	.110(*)	.347(**)
	Sig. (2-tailed)	.019	.134	.000	.027	.000
	N	403	404	403	407	403
diff_Q4.02	Pearson Correlation	-.074	.011	-.098	.046	.169(**)

"Scientific ideas can be changed"	Sig. (2-tailed)	.145	.822	.052	.365	.001
	N	392	393	392	396	392
diff_Q4.03 Most people can understand science.	Pearson Correlation	-.049	.123(*)	.093	.143(**)	.054
	Sig. (2-tailed)	.340	.015	.069	.005	.286
	N	386	387	386	390	386
diff_Q4.04 Scientists can always find the answers to their questions.	Pearson Correlation	.020	-.021	-.027	.059	.104(*)
	Sig. (2-tailed)	.686	.672	.594	.237	.040
	N	394	395	394	398	394
diff_Q4.05 Science is always difficult and boring.	Pearson Correlation	.046	.002	.180(**)	-.051	-.276(**)
	Sig. (2-tailed)	.362	.973	.000	.312	.000
	N	396	397	396	400	396
diff_Q4.06 People must understand science because it affects their lives.	Pearson Correlation	-.030	.042	-.031	.118(*)	.167(**)
	Sig. (2-tailed)	.552	.408	.540	.019	.001
	N	390	391	390	394	390
diff_Q4.07 Good scientists are willing to change their ideas when there is a new idea with sufficient evidence.	Pearson Correlation	-.034	-.046	.076	.145(**)	.074
	Sig. (2-tailed)	.504	.360	.131	.004	.144
	N	392	393	392	396	392
diff_Q4.08 I would want to do science-related work in my future.	Pearson Correlation	-.109(*)	.026	-.133(**)	.044	.215(**)
	Sig. (2-tailed)	.030	.613	.008	.381	.000
	N	394	395	394	398	394
diff_Q4.09 Scientists sometimes wait for several decades to prove scientific theories until technology is improved good enough to detect evidence in nature.	Pearson Correlation	.023	-.054	.058	.058	-.003
	Sig. (2-tailed)	.649	.282	.252	.248	.947
	N	393	394	393	397	393
diff_Q4.10 Only highly trained scientists can understand science.	Pearson Correlation	.019	-.098(*)	.067	.019	-.058
	Sig. (2-tailed)	.700	.050	.183	.702	.246
	N	399	400	399	403	399
diff_Q4.11 Scientists must report exactly what they observe.	Pearson Correlation	-.059	-.089	-.080	.062	.171(**)
	Sig. (2-tailed)	.244	.079	.115	.218	.001
	N	390	391	390	394	390
diff_Q4.12 I would like to be a	Pearson Correlation	-.057	-.042	-.087	.051	.162(**)
	Sig. (2-tailed)	.266	.409	.087	.314	.001

scientist.	N	387	388	387	391	387
diff_Q4.13 Scientific theories cannot always be proven with possible data in nature.	Pearson Correlation	.027	-.041	-.006	.033	.045
	Sig. (2-tailed)	.599	.422	.908	.514	.377
	N	392	393	392	396	392
diff_Q4.14 Science is useful only to scientists.	Pearson Correlation	-.023	.039	.068	-.033	-.119(*)
	Sig. (2-tailed)	.653	.442	.175	.513	.018
	N	395	396	395	399	395
diff_Q4.15 It is useless to listen to a new idea unless everybody agrees with it.	Pearson Correlation	-.002	.006	.066	-.043	-.130(**)
	Sig. (2-tailed)	.965	.908	.195	.394	.010
	N	391	392	391	395	391
diff_Q4.16 I may not make great discoveries, but working in science would be fun.	Pearson Correlation	-.070	.014	-.129(*)	.058	.228(**)
	Sig. (2-tailed)	.162	.779	.010	.244	.000
	N	396	397	396	400	396
diff_Q4.17 When scientists have a good explanation, they do not try to make it better.	Pearson Correlation	-.002	-.006	.050	.003	-.061
	Sig. (2-tailed)	.968	.909	.322	.953	.226
	N	395	396	395	399	395
diff_Q4.18 Scientists should not criticize each other's work.	Pearson Correlation	.000	.086	.015	-.014	-.035
	Sig. (2-tailed)	.996	.090	.773	.781	.488
	N	393	394	393	397	393
diff_Q4.19 If one scientist says an idea is true, all other scientists will believe it without doubt.	Pearson Correlation	-.033	.029	.077	-.022	-.121(*)
	Sig. (2-tailed)	.521	.567	.129	.668	.017
	N	389	390	389	393	389
diff_Q4.20 It is worth to spend time and money to do science research.	Pearson Correlation	.018	-.023	-.070	.105(*)	.209(**)
	Sig. (2-tailed)	.719	.649	.160	.034	.000
	N	399	400	399	403	399
diff_Q4.21 It is necessary for people to understand science.	Pearson Correlation	.047	-.050	.020	.174(**)	.176(**)
	Sig. (2-tailed)	.352	.326	.690	.001	.000
	N	393	393	392	396	392

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

▪ Significant Results

The one who had higher interest increase about science (the difference between post-interest and pre-interest, (post interest) – (pre interest))

1) Had less visited LIGO before the field trip. (r=-.138, p=.006)
2) Had a tendency of less visiting science museums as well (r=-.043, p=.388)

   -> The result 1) indicates that the students who had less visited LIGO had higher increase in their interest about science after this field trip. The result 2) shows the same tendency for science museums although it was not significant enough.

3) Had higher post interest after the field trip. (r=0.364, p=0.000)
4) Had more to think that "Science is fun." (diff_Q4.01) (r=0.347, p=0.000)
5) Had more to think that "Scientific ideas can be changed." (diff_Q4.02) (r=0.169, p=0.001)
6) Had more to think that "Scientists can always find the answers to their questions." (diff_Q4.04) (r=0.104, p=0.040)
7) Had less to think that "Science is always difficult and boring." (diff_Q4.05) (r=-0.276, p=0.000)
8) Had more to think that "People must understand science because it affects their lives." (diff_Q4.06) (r=0.167, p=0.001)
9) Had more to think that "I would want to do science-related work in my future." (diff_Q4.08) (r=0.215, p=0.000)
10) Had more to think that "Scientists must report exactly what they observe." (diff_Q4.11) (r=.171, p=.001)

11) Had more to think that "I would like to be a scientist." (diff_Q4.12) (r=.162, p=.001)

12) Had less to think that "Science is useful only to scientists." (diff_Q4.14) (r=-.119, p=.018)

13) Had less to think that "It is useless to listen to a new idea unless everybody agrees with it." (diff_Q4.15) (r=-.130, p=.010)

14) Had more to think that "I may not make great discoveries, but working in science would be fun." (diff_Q4.16) (r=.228, p=.000)

15) Had less to think that "If one scientist says an idea is true, all other scientists will believe it without doubt." (diff_Q4.19) (r=-.121, p=.017)

16) Had more to think that "It is worth to spend time and money to do science research." (diff_Q4.20) (r=.209, p=.000)

17) Had more to think that "It is necessary for people to understand science." (diff_Q4.21) (r=.176, p=.000)

This can be summarized into three categories:

The one who had higher interest increase about science ((post interest) – (pre interest))

Category A) Had more interest about science:

Had more to think that "Science is fun." (diff_Q4.01) (r=0.347, p=0.000)

Had less to think that "Science is always difficult and boring." (diff_Q4.05) (r=-0.276, p=0.000)

Had more to think that "I would want to do science-related work in my future." (diff_Q4.08) (r=0.215, p=0.000)

Had more to think that "I would like to be a scientist." (diff_Q4.12) (r=.162, p=.001)

Had more to think that "I may not make great discoveries, but working in science would be fun." (diff_Q4.16) (r=.228, p=.000)

Category B) Had better understanding about science & scientists:

Had more to think that "Scientific ideas can be changed." (diff_Q4.02) (r=0.169, p=0.001)

Had more to think that "Scientists must report exactly what they observe." (diff_Q4.11) (r=.171, p=.001)

Had less to think that "It is useless to listen to a new idea unless everybody agrees with it." (diff_Q4.15) (r=-.130, p=.010)

Had less to think that "If one scientist says an idea is true, all other scientists will believe it without doubt." (diff_Q4.19) (r=-.121, p=.017)

Category C) Had better understanding about the necessity of science in our lives
(or, Gained more open-minded about science)

Had more to think that "People must understand science because it affects their lives." (diff_Q4.06) (r=0.167, p=0.001)

Had more to think that "It is worth to spend time and money to do science research." (diff_Q4.20) (r=.209, p=.000)

Had more to think that "It is necessary for people to understand science." (diff_Q4.21) (r=.176, p=.000)

► Analysis Plan for Age difference:

There were only 36 students for 9th graders, and the rest were either 5th or 6th graders in Spring 2013 data. Due to the lack of the number of 9th graders, I collected additional data for 9th graders in Spring 2014. After completing with excel filing, I will analyze the data by comparing the two groups, one for younger students (5th and 6th graders) and the other for elder students (9th graders), and expect to see any differences by age.

2.2. Research Paper Outline

This study needs data filing for the data that were newly collected this spring. Once the data filing is finished, the analysis will be conducted again for the combined data (both data from spring 2013 and spring 2014). As for now, I have a rough outline for the paper draft at this point as below.

Outline of the paper

Introduction

Literature Review

Studies about students' attitudes toward science and scientists

Studies about students' learning in science museums

Method

Setting: LIGO Field Trip program

Participants and Data Collection

Analysis: mixed-methods (descriptive statistics, t-test, Pearson's correlation, and qualitative data analysis with grounded theory approach)

Variables:

- Age (5^{th}/6^{th} grade vs. 9^{th}/10^{th} grade)
- Number of previous visits to LIGO (0, 1, 2, more than 3)
- Number of previous visits to other Science Museums (0, 1, 2, more than 3)

Findings

A. Attitudes and Interest about Science

A1. Likert-Type Questions: Interest degree, Responses to Likert-type questions

A2. Conceptions about Science (the effect and the necessity of science research, etc.)

B. Understanding of Basic Scientific Concepts relevant to the Science Mission

Scoring students' responses based on rubrics. And, comparing the results between pre and post.

B1. Gravity

B2. Light

B3. Sound

C. Understanding of a Science Mission

Open-coding on students' responses, and categorizing them. And, comparing the results between pre and post.

Discussion

Some discussions from the preliminary analysis are: The 4-hour field trip to LIGO and its education center gave the visiting students positive impacts about science and scientists. This field trip led the students to recognize that science can be fun and to consider science as their future career positively. While it was a short visit, it showed the evidence that the students could actually gain content knowledge as well from the visit to a science museum. This study supports public outreach programs for professional science research centers because they can lead to students broadening their view of science and helping them recognize the value of science research.

The overall contents of the paper would be similar to what I had presented at AAS meeting (Jun 5th 2014, Boston, MA). But the findings and discussions will be updated with findings found from new analysis. (Please find the attached file for the poster presented at the AAS 224th meeting: PRINTaas224_hyunju.pdf)