

# Space Science SSEAT 2019 Final Report

Project Year: 2019 - 2020

PD Dates: July 8-12, 2019

Location: St. Peter School (100 Concord Ave, Cambridge, MA 02138) (at CfA)

Participants: 15 local teachers from the districts with high proportions of underserved students in the greater Boston area

Program schedule overview:

Smithsonian Science Education Academies for Teachers: Space Science July 8 - 12, 2019						
	Introduction to Astronomy	Seasons, Old Observatory & Historical Archives	Moon Phases & Eclipses, Space Telescope	Observational Astronomy, Galaxies & the Universe	Applications to Classroom	
Date	Monday, July 8, 2019	Tuesday, July 9, 2019	Wednesday, July 10, 2019	Thursday, July 11, 2019	Friday, July 12, 2019	Date
Time						
8:00-8:30a	Breakfast & Registration pre-attitude survey	Breakfast	Breakfast	Breakfast	Breakfast	8:00-8:30a
8:30-9:00a	Welcome & pre-concept survey	Visualization in Astronomy <i>Alyssa Goodman</i>	WWT ThinkSpace Seasons (Does distance impact Seasons? Wrapup and summary) - Pat & Harry	MicroObs Day 2: Astronomical Images & Image Processing - Mary	Science Inquiry & Phenomena <i>Hyunju</i>	8:30-9:00a
9:00-9:30a	Intro activity (Scale) - Mary 9:00-9:30	WWT ThinkSpace Seasons 8:45-10:00 (Intro to curriculum, Spatial thinking activity, Modeling Day/Night, Apparent path of the Sun through the sky) - Pat & Harry	WWT ThinkSpace Moon (Earth-Moon scale model; Moon phases model activity; Connecting space and Earth-based perspectives of the Moon) - Pat & Harry		MicroObservatory Sharing your images 8:45-9:45 - Mary	9:00-9:30a
9:30-10:00a	SSEAT Program overview	break	break	break	break	9:30-10:00a
10:00-10:30a	Light & Color - activity 9:45-10:45 Mary & Pat	break	break	MicroObs Day 2: Astronomical Images & Image Processing, Processing own astronomical images - Mary	Reflection & Planning Time 10:00-11:30 - Mary & Pat	10:00-10:30a
10:30-11:00a	break	WWT ThinkSpace Seasons 10:15am-11:45 (Sun angle and intensity, Earth's tilted axis, How the tilted axis affects sun angle) - Pat & Harry	Sun-Earth-Moon (SEM) Model Activity 10:30 - 11:30 - Carol			10:30-11:00a
11:00-11:30a	MicroObs Day 1: basic concept 11:00-12:00 Mary		Lunch: 11:30-12:00	Lunch: 11:30-12:00	Summary, Evaluation, & Post-test	11:00-11:30a
11:30a-12:00p		Lunch 11:45-12:15				11:30a-12:00p
12:00-12:30p	Lunch 12:00-12:30	WWT ThinkSpace Seasons (Changing hours of daylight) 12:15-1:00 - Pat & Harry	WWT ThinkSpace Moon (Hula hoop eclipse model; Review) 12:00 - 12:45 Pat & Harry	Why make a map of the Universe (Galaxies & Universe) 12:00-1:00 Margaret Geller	Lunch & Dismissal	12:00-12:30p
12:30-1:00p	Student Misconceptions in Astronomy (and what to do about them) 12:30-1:30 Phil Sadler	MicroObs: Take your own images	Break & Go on to a bus	Intro of CfA labs & moving to CfA		12:30-1:00p
1:00-1:30p		Group Photo	Bus: travel to Burlington			1:00-1:30p
1:30-2:00p	break					1:30-2:00p
2:00-2:30p	MicroObs Day 1: Take your own images 1:45-3:15 Mary	CfA/SAO tour 1:30-3:15 (1 hr 45 min) split into 4 groups Astronomical Plate Stacks & DASCH project, Great Refractor, & MicroObservatory telescope - Lindsay, Mary, Frank & Erika	Chandra X-ray Operation Center tour 1:30-3:00 Jonathan & Chris	CfA Lab Tours (6 labs or 5 labs) 1:15-3:00 3 groups, visiting 2 labs McCarthy's lab (Kevin, Jessy, Brandon, B112), Oberg's lab (Mahesh, PG), Walsworth's lab (Oren, PG), Josh's lab (Jaesub, PG), Romains' lab (Ric, B1*)		2:00-2:30p
2:30-3:00p						2:30-3:00p
3:00-3:30p	Reflection & Summary, Daily evaluation	Reflection & Summary, Daily evaluation	Reflection & Summary, Daily evaluation	Coming back to school, Jigsaw		3:00-3:30p
3:30-4:00p			Bus: travel back to Cambridge	Reflection & Summary, Daily evaluation		3:30-4:00p

For more information of the program, please see the academy website:

<https://sseatspd.wixsite.com/spacescience2019>

Data Collected:

- 1) Summer 2019: Pre/post Concept Survey; Pre/post Attitude Survey; and Daily & at the end-of-Week Evaluation
- 2) Spring & Summer 2020: Follow-up Implementation Survey

Analysis:

Mixed method (descriptive statistics, t-test, and grounded theory approach)

## A. Understanding of Science Concepts (Pre/Post Concept Survey)

To understand the participants' knowledge gain, a concept survey was conducted before they attended the academy (pre-test) and after they attended the whole week-long academy (post-test). There were total 20 concept questions (16 multiple-choice questions, 3 open-ended questions, and 1 open-ended image description question that was not counted on the scores), and the same questions were asked for both pre and post-tests. Each multiple-choice question was scored for 1, and open-ended questions were measured with rubrics (Table 1), scoring 2, 3, or 4 points.

Table 1. Rubrics for open-ended questions			
Points	Q.18 (2 points)	Q.19 (4 points)	Q.20 (3 points)
0	No response, or wrong answer	No response, or wrong answer	No response, or wrong answer
1	May provide some relevant information partly, but not enough	Provide too little &/or partially wrong information (Not providing any of three concepts: - tilt of the Earth's axis - length of daytime - direct/indirect sun or surface area)	Providing too little & wrong information (Not providing any of two concepts: - Length of daytime and nighttime would be the same - No seasonal change)
2	Provide correct information	Provide some correct, yet not full, or could partially wrong information (or, mentioned one of the three concepts)	Providing some correct, yet not full, or could partially wrong information (or, mentioned one of them)
3	-	Providing correct & full information (or, mentioned two of the three concepts)	Providing correct & full information (or, mentioned both of them)
4	-	Providing more detailed information than above. (or, mentioned all three concepts)	-

The total maximum scores that they could get is 25 points. Table 2 shows each teacher's score at pre and post, and their gains (post-pre). Among the 15 participants, 14 were matched between pre and post. To find out if the gain was statistically significant, paired-samples t-test was conducted (Table 2).

Table 2. Pre/Post-Concept Test Result (max. 25 scores)			
teachers	Pre	Post	Gain
Teacher 01	20	22	2
Teacher 02	10	15	5
Teacher 03	14	16	2
Teacher 04	13	23	10
Teacher 05	12	13	1
Teacher 06	25	25	0
Teacher 07	5	12	7
Teacher 08	18	19	1
Teacher 09	18	18	0
Teacher 10	8	11	3
Teacher 11	19	19	0
Teacher 12	15	22	7
Teacher 13	11	21	10
Teacher 14	16	24	8
<i>Mean</i>	<i>14.6</i>	<i>18.6</i>	<i>4.0</i>
<i>STDEV</i>	<i>5.3</i>	<i>4.6</i>	<i>3.74</i>
<i>Std. Error of Mean</i>	<i>1.41</i>	<i>1.22</i>	<i>1.00</i>
<i>t-test (two-tailed)</i>		<i>p</i>	<i>.0015</i>

The result shows that the participants scored statistically significantly high in the post-test (M=18.6, SD=4.6) than in the pre-test (M=14.6, SD=5.3);  $t(13) = 4.0, p < .01$ . In other words, *the participants had statistically significant knowledge gain after participating in the week-long Space Science SSEAT academy.*

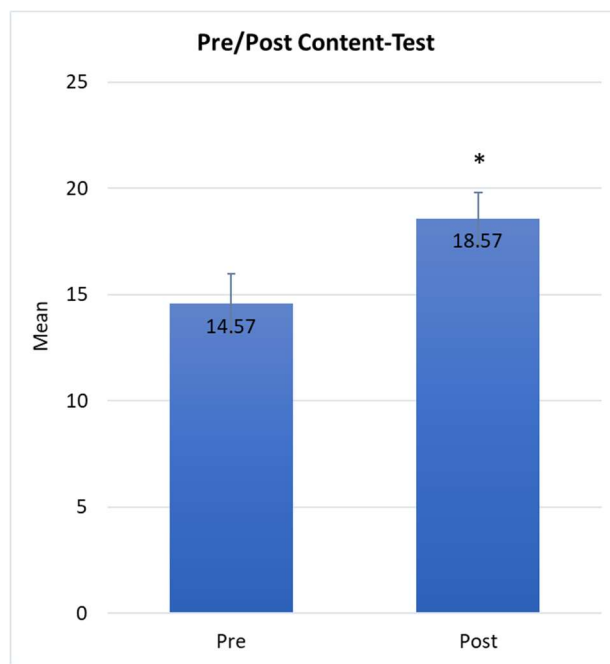


Figure 1. Pre/Post Concept-test result (n=14)

## B. Teachers' Perceptions about their Learning (Pre/Post Attitude Survey)

An attitude survey was conducted before teachers attended the academy (pre-survey) and after they attended the week-long academy (post-survey) to find out if the learning experience at the academy may have influence their perceptions about self-efficacy and interest. The attitude survey consisted of both Likert-scale questions and open-ended questions.

### B.1. Likert-Scale Questions Data Result

The Likert-scale (5-scale) questions were designed to investigate the following 6 constructs: 1) the perception about their content knowledge; 2) perception about their pedagogical knowledge; 3) their perspective about implementation; 4) their interest and motivation about science; 5) their understanding of the Nature of Science; and 6) their teaching confidence.

Among the 15 participants, 14 were matched between pre and post, and the mean values and standard error of the means for each construct were measured (Table 3).

Table 3. Pre/Post Attitude Survey Number of Participants (n=14, matched)		Pre		Post	
		Mean	Std. Error Mean	Mean	Std. Error Mean
A. Self-Efficacy of Content Knowledge	<ul style="list-style-type: none"><li>• I have a good understanding of the concept of seasonal change.</li><li>• I have a good understanding of the concept of lunar phases and eclipses.</li><li>• I am knowledgeable on space science concepts that I teach.</li></ul>	4.26	0.14	4.65	0.09
B. Self-Efficacy of Pedagogical Knowledge	<ul style="list-style-type: none"><li>• I am knowledgeable on student misconceptions in space science.</li><li>• I have pedagogical ideas to teach science as inquiry.</li><li>• I am knowledgeable of using various forms of representation in my instruction (visual images, models, etc.).</li></ul>	3.94	0.12	4.71	0.08
C. Perspective about Implementation	<ul style="list-style-type: none"><li>• I can integrate technology in my instruction.</li><li>• Integrating technology can enhance students learning and interest in science.</li><li>• I am comfortable with implementing hands-on materials/resources in my instruction.</li></ul>	4.67	0.09	4.88	0.07
D. Interest & Motivation	<ul style="list-style-type: none"><li>• I am interested in learning about astronomy and space science.</li><li>• It is interesting to learn about cutting-edge science research findings.</li></ul>	4.80	0.09	4.82	0.10

	<ul style="list-style-type: none"> <li>• Meeting scientists in the field motivates me to teach science.</li> <li>• Learning about science history enhances my interest in science.</li> </ul>				
E. Understanding of Nature of Science	<ul style="list-style-type: none"> <li>• Understanding about how scientists proceed science research helps me teach science in class.</li> <li>• Scientific method is an iterative process.</li> <li>• Science theories should not be changed over time. (N)</li> <li>• Science research should be independent, not interdisciplinary. (N)</li> </ul>	4.48	0.15	4.74	0.08
F. Confidence about Teaching	<ul style="list-style-type: none"> <li>• I am confident to teach science.</li> <li>• I am comfortable teaching space science in my class.</li> <li>• There are space science concepts that I get confused when I teach. (N)</li> </ul>	3.46	0.17	3.81	0.22

Note: Those negatively asked questions (with the sign N in the table) were converted into the adjusted scales in calculation.

And, Figure 3 presents the means for each construct between pre and post.

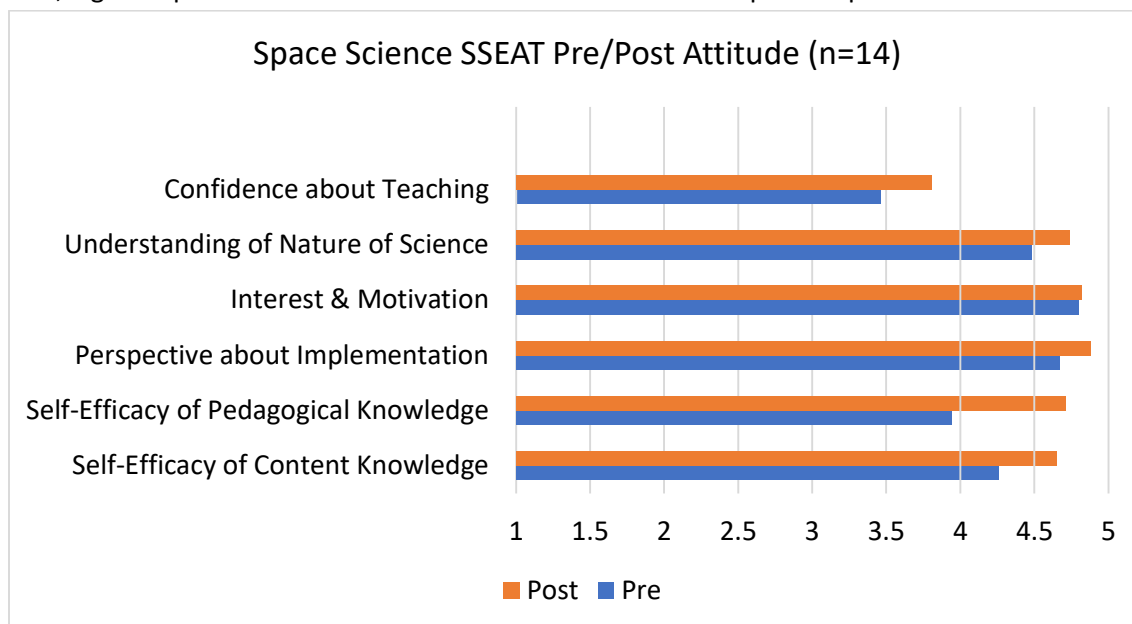


Figure 2. Teacher perceptions about their learning experience at the Space Science SSEAT

The results show that the participants' perceptions of their content knowledge, pedagogical knowledge, perspective about implementation, interest and motivation, understanding of nature of science, and their teaching confidence were all increased after they attended the week-long academy. Among the six constructs, the construct of *Interest & Motivation* showed the smallest change, which was high already before they attended the academy. The

participants' self-efficacy of pedagogical knowledge increased the most among the six constructs.

To better understand the changes, repeated measures (paired-sample) t-test was conducted for each construct (Table 4). The changes were statistically significant for the constructs of A, B, and C, but were not significant for D, E, and F in the 95% confidence level. In other words, the participants thought that their content knowledge was significantly increased in the post ( $M=4.65$ ,  $SD=0.35$ ) than in the pre ( $M=4.26$ ,  $SD=0.53$ ),  $t(13)=2.62$ ,  $p < .05$ ; their pedagogical knowledge was significantly increased in the post ( $M=4.71$ ,  $SD=0.32$ ) than in the pre ( $M=3.94$ ,  $SD=0.46$ ),  $t(13)=6.56$ ,  $p < .05$ ; and their perception about their ability to implement what they learned at the academy was higher in the post ( $M=4.88$ ,  $SD=0.25$ ) than in the pre ( $M=4.67$ ,  $SD=0.32$ ),  $t(13)=2.39$ ,  $p < .05$ . On the other hand, their interest (D), their understanding of the nature of science (E), and their confidence of teaching (F) did not show significant change during the week-long academy.

Table 4. T-test result: teacher perception

Constructs		n	Mean	SD	t	df	p (two-tailed)	95%
A. Self-Efficacy of Content Knowledge	Pre	14	4.26	0.53	2.62	13	.021	Sig.
	Post	14	4.65	0.35				
B. Self-Efficacy of Pedagogical Knowledge	Pre	14	3.94	0.46	6.56	13	1.8E-05	Sig.
	Post	14	4.71	0.32				
C. Perspective about Implementation	Pre	14	4.67	0.32	2.39	13	.033	Sig.
	Post	14	4.88	0.25				
D. Interest & Motivation	Pre	14	4.80	0.33	0.21	13	.836	No sig.
	Post	14	4.82	0.36				
E. Understanding of Nature of Science	Pre	14	4.48	0.56	2.04	13	.063	No sig.
	Post	14	4.74	0.31				
F. Confidence about Teaching	Pre	14	3.46	0.65	1.50	13	.159	No sig.
	Post	14	3.81	0.84				

Although it had a small sample size, the results show some meaningful information. Attending the week-long academy influenced the participants' perception about their content knowledge (A), pedagogical knowledge (B), and their ability to implement (C) to get increased in a positive way. Their interest and motivation (D) and the understanding of nature of science (E) were quite high in both pre and post although they did not show a significant change. However, their

teaching confidence (F) was still low in post. During the academy, the participants “attended” the sessions, but had no opportunities to practice it. It may have not been enough to increase their teaching confidence only by “attending” the week-long academy. *It suggests that some more intervention may be needed to affect their teaching confidence, and it could be a longer PD or the actual practicing of the implementation.* It would need an extended study to find it out.

## B.2. Open-Ended Questions Data Result

Below is summarized the participants’ responses to the open-ended questions of the pre/post-attitude survey. In the pre-survey, the participants’ goals and expectation of the academy was asked. And in the post-survey, three questions were asked: their main key take-aways of the week, and their thoughts about the influence of the academy experience on their teaching and students.

### 1. Pre-Survey: Goals & expectations of the Space Science SSEAT

(Q. What are your expectations of the Space Science SSEAT? What goals do you have in attending the SSEAT?)

- Increase understanding of space science concepts & topics
  - *“My expectations are to gain a greater understanding on space topics.”* (ID: 02472)
  - *“To broaden my understanding of academic areas to increase my knowledge to better instruct my students”* (ID:82666)
  - *“I’m hoping to get a deeper understanding of a couple topics, an overview of astronomy,”* (ID: Lucky)
- Getting ideas & resources for instruction
  - *“Work with resources that are shared w/ teachers to enhance pedagogical understanding + progression w/ space science and student understanding”* (ID: 01774)
  - *“I am hoping to get some ideas for the new astronomy class that I will be teaching in the fall.”* (ID: 13021)
  - *“I hope to gain new ideas for my Astronomy unit both conceptual and pedagogical”* (ID: 88337)
  - *“I am looking for fresh ideas to teach Space Science concepts- especially those that are project based”* (ID: L2578)
  - *“I am interested in gaining new ideas and resources to enrich the way I deliver earth/space science content”* (ID: LOLA1)
  - *“I would like to learn new hands-on approaches to teaching Space Science.”* (ID: 11123)
  - *“and leave with ideas and activities to use in my class”* (ID: Lucky)
  - *“Resources for students”* (ID: 57910)
  - *“new resources/activities to implement,”* (ID: LPAGE)
- Learning about Misconceptions
  - *“Clarification of misconceptions.”* (ID: 57910)
  - *“My goals are to help dispel students misconceptions about space sciences”* (ID: 02472)
- Working with real data, having more active experience
  - *“to see current research facilities”* (ID: 01774)
  - *“practice using online resources for my students to access real data”* (ID: 11123)



- *"I want to gain more active experiences (x-ray telescope control center tour for example) to share with my students."* (ID: 44750)
- *"connections to local institutions and researchers, "real" research/citizen science ideas,"* (ID: LPAGE)
- Others
  - Integrating technology: *"I want to gain experience with computer software so I can incorporate more technology into my astronomy unit"* (ID: 44750)
  - *"more confidence in modeling/explaining spatial components"* (ID: LPAGE)

## 2. Post-Survey: Key Take-aways

(Q. What were your key takeaways from the week-long experience at the Space Science SSEAT academy?)

- Hands-on activities, resources & ideas to implement into class
  - Confidence: *"I feel confident in bringing hands-on activities to the classroom"* (ID: 33027)
  - *"there are some great resources to help accentuate student learning of space science, many ideas I knew are accurate, but now I can process and plan them into instruction"* (ID: 01774)
  - *"Many teachers looking for new ideas, SSEAT well worth it! Very productive, hands-on materials + activities combined"* (ID: 11123)
  - *"I have a better idea of how to teach some of the content conceptually. I also have some great lesson plans that I can use/adapt for my classroom"* (ID: 13021)
- Better understanding of the Nature of Science (NoS) & meeting with scientists
  - *"science is challenging and amazing and even scientists in the field get confused"* (ID: 57910)
  - *"Astronomy is a collaborative science"* (ID: 1119L)
  - *"w/ meeting actual scientists"* (ID: 11123)
- Getting to know & addressing Misconceptions
  - *"Address student misconceptions,"* (ID: 82666)
  - *"the importance of misconceptions"* (ID: 88337)
  - *"need to know potential misconceptions ahead of time, use pre-assessment to discover who has/what are the misconceptions"* (ID: L2578)
  - *"Anticipate misconceptions,"* (ID: LOLA1)
- Getting to know pedagogical ideas
  - *"address distances of planets accurately, provide models and identify weakness by teacher/student to improve critical thinking"* (ID: 82666)
  - *"integration of student controlled tech, modeling"* (ID: 88337)
  - *"photos can be used to generate cognitive dissonance"* (ID: L2578)
  - *"students need to interact with visual models, find connections + resources in the science fields to enrich student experience"* (ID: LOLA1)
  - *"misconceptions + phenomena should be intentional parts of planning + assessing"* (ID: LPAGE)
  - *"use physical models, identify + explain misconceptions"* (ID: Lucky)
- Others: concept specific
  - *"understanding perspective is key to S-E-M system" ... "EM spectrum can be observed to show many different things and each wavelength require unique technological solutions"* (ID: LPAGE)
  - *"Microobservatory!"* (ID: Lucky)

### 3. Post-Survey: perception about the influence on teaching

(Q. How do you think your learning experience at the Space Science SSEAT affect your teaching practices or philosophy?)

- Reinforce teaching practice with inquiry and engagement
  - *"This experience has helped reinforce areas of practice for student inquiry and expanded thoughts on lesson design"* (ID: 01774)
  - *"It will absolutely effect my teaching practice with the tools given I feel that my astronomy will be more engaging for students (and hopefully) be more effective"* (ID: 88337)
  - *"It will provide more tools, confidence, and excitement"* (ID: 1119L)
  - *"integrating student driven technology for inquiry"* (ID: LPAGE)
- Using & better reflection of student misconception
  - *"+ assessment surrounding student misconception"* (ID: 01774)
  - *"Reflect on mediums of instruction and areas of student misconceptions"* (ID: 82666)
- More ways to approach various students
  - *"I'm thrilled to have more ways to help all of my students learn (ELL, SPED, language based, accelerated, grade level)"* (ID: 11123)
  - *"I have more tools to teach space science- this is helpful because of diverse learning styles"* (ID: L2578)
- Better explaining with better understanding of concepts
  - *"I will be able to explain things better because I have increased my understanding of concepts"* (ID: 13021)
  - *"Eliciting, addressing, and assessing, models- more intentional discussion of limitations"* (ID: LPAGE)
- Better to do with experiments and exploration
  - *"Of course yes because now I can bring astronomy to the students and make them feel that they are young astronomers"* (ID: 33027)
  - *"Better manipulatives for student exploration and understanding."* (ID: 82666)
- Inspiration & recharged enthusiasm
  - *"I feel inspired and my enthusiasm has been recharged to examine my current practices and incorporate new ideas + multiple modalities"* (ID: LOLA1)
- Others, general
  - *"This week will make me a better teacher"* (ID: 57910)
  - *"The way content was presented gave me ideas for how to teach!"* (ID: Lucky)

### 4. Post-Survey: perception about the influence on students

(Q. How will your students be affected by your learning experience at the Space Science SSEAT?)

- Increasing interest about science
  - *"They will be reintroduced and enthusiastic about science!"* (ID: 01774)
  - *"Their interest in space science will increase 10 fold"* (ID: 33027)
- More hands-on activities and engagement
  - *"They will be able to have more hands on activities"* (ID: 13021)
  - *"Hopefully lessons will be more engaging, less teacher directed, more inquiry based"* (ID: L2578)

- “They will have opportunities to use technology, and more interactive lessons” (ID: Lucky)
- “I think they will enjoy the new tech that I will be introducing them to” (ID: 88337)
- Better understanding of concepts
  - “they’ll actually learn about space now :), inspiration + excitement, local experts + field trip potential?, hopefully a clearer understanding of scale and the S-E-M system” (ID: LPAGE)

## C. Teachers’ Perceptions about Their Learning Experience at Different Modes of PD Sessions

An evaluation survey was conducted at the end of each day (daily evaluation) and at the end of the week (program evaluation). The evaluation survey was designed to find out the participants’ perceptions about their learning experience at each PD session. The program schedule is attached in the first page of this report. The week-long program PD sessions are classified into six different modes, which are presented by different color codes in the schedule. The detailed description of the sessions is summarized in Table 5.

Table 5. Categories of Mode

Mode	Session	Description of the Session	Provided Day
<b>Hands-on Classroom Activity (no technology integrated)</b>	Scale Activity	Using picture cards and inquiry questions, participants discussed about several sets of scale (e.g. distance, size, age of the Universe, etc.)	Monday
	Light & Color	Using light and colored cellophane papers, the participants learned about the characteristics of light.	Monday
	SEM Activity	Using the Sun-Earth-Moon model, the participants discussed about the concepts of seasons, lunar phases, and the eclipses.	Wednesday
<b>Hands-on Classroom Activity with Technology Integration</b>	WorldWide Telescope ThinkSpace Labs (Seasons, and Lunar Phases)	The participants learned about how to integrate the WWT and the Thinkspace lab’s lesson plans about seasons and lunar phases.	Tuesday & Wednesday
<b>Science Data Procedure Experience with Technology Integration</b>	MicroObservatory	The participants learned to use MicroObservatory tool to take the images of astronomical objects and went through image process as astronomers do.	Monday Thursday & Friday

<b>Science Lecture</b>	Astronomy Misconceptions	Invited speaker talked about his research of misconceptions in astronomy that many students have in common.	Monday
	Visualization in Astronomy	Invited speaker talked about her research about visualization in astronomy.	Tuesday
	Why make a map of the Universe	Invited speaker talked about her research about galaxy map and the Universe.	Thursday
<b>Field Trip</b>	CfA Observatory & Historical Archives	The participants visited the CfA's old observatory and its historical plate archives, as well as microObservatory telescope.	Tuesday
	Chandra X-ray Observatory Operations Control Center	The participants visited the Chandra X-ray Observatory Operations Control Center. The Chandra OCC is in charge of operating and maintaining the Chandra X-ray telescope in space, and many X-ray astronomers use the Chandra images for their research.	Wednesday
	CfA Research Labs	The participants visited the CfA's research labs. The labs were two X-ray labs (hard x-ray, soft x-ray optics), two astrobiology labs, and one quantum mechanics/cosmology lab.	Thursday
<b>Science Inquiry &amp; Planning</b>	Science Inquiry & Phenomena	The participants learned about how science inquiry with phenomena can be applied in science class using photos.	Friday
	Reflection & Planning Time	The participants had time to reflect their learning of the week, and made a plan for their class integrating their learning of the week.	Friday

### C.1. Likert-questions Response Result

Each day, the participants were asked to reflect their learning experience for each session. The evaluation survey consisted of both Likert-items and open-ended questions. The Likert-items asked 7 questions, which are 7 learning categories: 1) This session increased my understanding of science concept (Content Knowledge, CK); 2) I learned something new from the session (something new); 3) I gained pedagogical ideas from the session that I can practice in my class (Pedagogical Content Knowledge, PCK); 4) I can easily bring what I learned from the session to my class (Implement); 5) The session increased my interest about space science (Interest); 6) The session helped me to better understand how scientists proceed their research (NoS); and 7) The session promoted my ability to teach science (teaching confidence). Their responses to each choice (strongly agree, agree, neutral, disagree, strongly disagree) for each item were counted for each mode throughout the week. The result is summarized in Table 6.

Table 6. Number of responses for each session mode

		CK	something new	PCK	Implement	Interest	NoS	Teaching confidence
Hands-on Classroom Activity (no technology integrated)	Strongly agree	16	22	24	24	15	9	21
	Agree	18	14	12	12	16	11	14
	Neutral	4	2	1	1	5	18	3
	Disagree	0	0	1	1	0	0	0
	Strongly disagree	0	0	0	0	0	0	0
	total n	38	38	38	38	36	38	38
Hands-on Classroom Activity with technology integration	Strongly agree	16	21	19	20	20	11	18
	Agree	8	3	5	4	4	6	6
	Neutral	0	0	0	0	0	7	0
	Disagree	0	0	0	0	0	0	0
	Strongly disagree	0	0	0	0	0	0	0
	total n	24	24	24	24	24	24	24
Science Data Procedure with technology integration	Strongly agree	19	26	21	25	22	20	23
	Agree	18	11	15	11	14	13	14
	Neutral	1	1	2	2	1	5	1
	Disagree	0	0	0	0	0	0	0
	Strongly disagree	0	0	0	0	0	0	0
	total n	38	38	38	38	37	38	38
Science Lecture	Strongly agree	21	28	20	18	21	25	21
	Agree	15	9	16	16	16	6	15
	Neutral	3	2	1	3	1	8	3
	Disagree	0	0	1	2	0	0	0
	Strongly disagree	0	0	0	0	0	0	0
	total n	39	39	38	39	38	39	39
Field Trip	Strongly agree	30	34	9	12	32	36	15
	Agree	6	3	16	16	4	1	18
	Neutral	2	1	9	7	2	1	5
	Disagree	0	0	3	2	0	0	0
	Strongly disagree	0	0	0	1	0	0	0
	total n	38	38	37	38	38	38	38
Science Inquiry & Planning	Strongly agree	15	17	22	22	18	12	22
	Agree	7	6	4	4	4	6	4
	Neutral	3	3	0	0	4	6	0
	Disagree	1	0	0	0	0	2	0
	Strongly disagree	0	0	0	0	0	0	0
	total n	26	26	26	26	26	26	26

To better understand the participants' perception about each session mode per each learning category, the percentages of the responses to each choice were calculated for each session mode and presented it by each learning category in the below figures (Figures 4 - Figure 10).

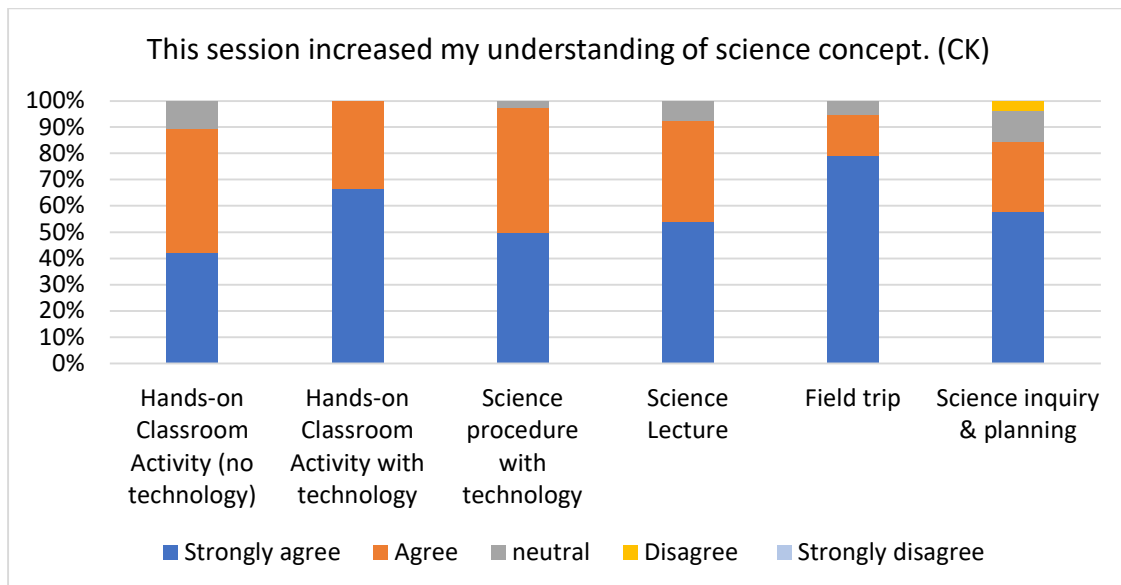


Figure 3. Teacher Perception about Content Knowledge depending on session modes

Figure 4 shows the participants' responses to the question, "This session increased my understanding of science concepts." The percentage of *strongly agree* was the highest at the field trip, then at the hands-on classroom activity with technology integration sessions. The participants thought that they gained content knowledge the most at the field trip, where they could interact with scientists in their space.

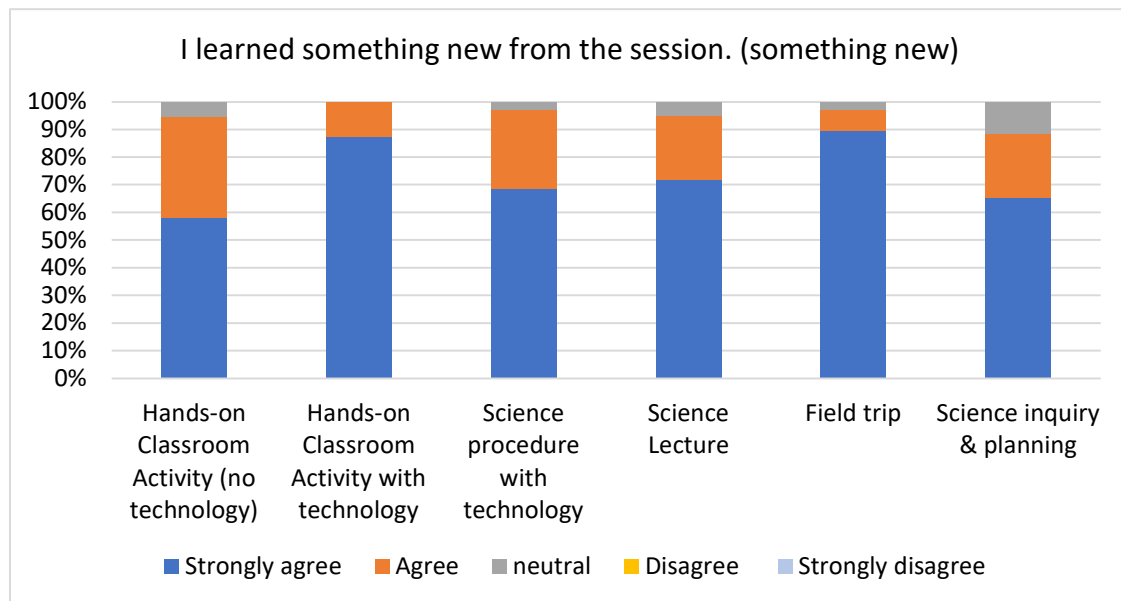


Figure 4. Teacher Perception about Learning Something New depending on session modes

Figure 5 shows that the participants thought they learned something new the most at the field trip and the hands-on classroom activity with technology integration sessions. This result is similar to what we saw in Figure 4.

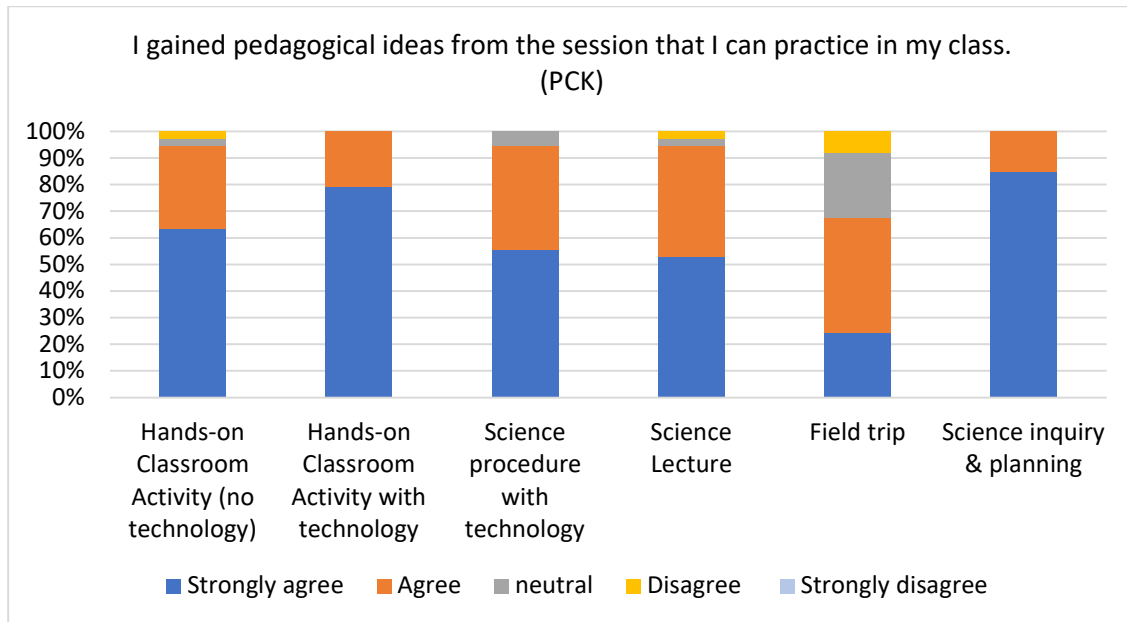


Figure 5. Teacher Perception about Pedagogical Content Knowledge depending on session modes

The participants thought that they learned the pedagogical content knowledge the most at the science inquiry and planning sessions (Figure 6). The hands-on classroom activity with technology integration showed high as well in this category.

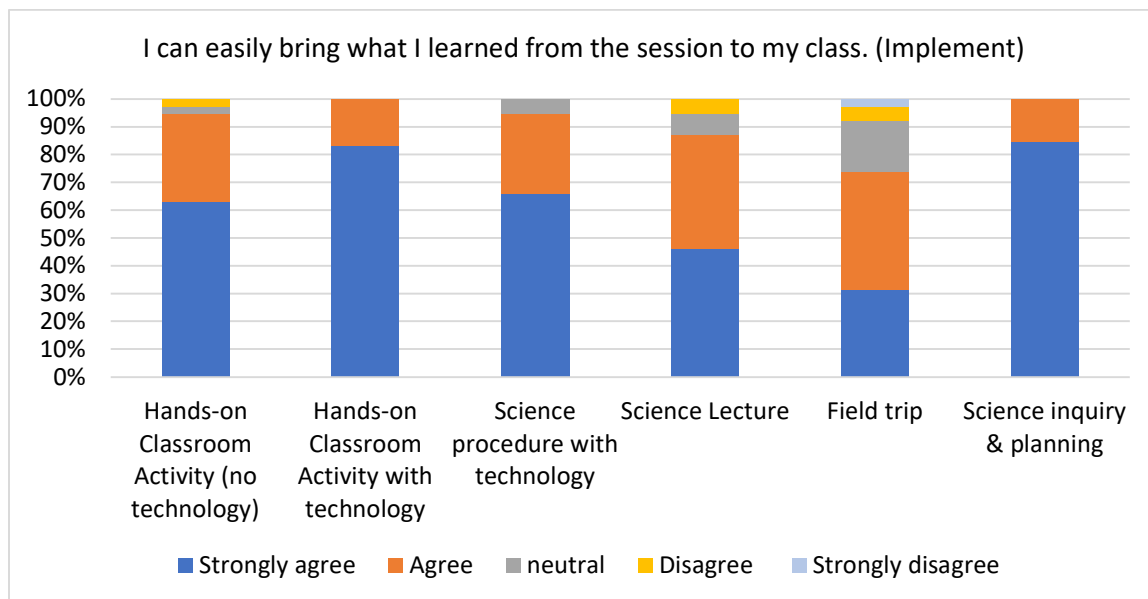


Figure 6. Teacher Perception about Implementation depending on session modes

The participants thought that they found the contents from the science inquiry & planning session and the hands-on classroom activity with technology integration session were easy to bring to their class (Figure 7). This result is similar to what we saw in Figure 6.

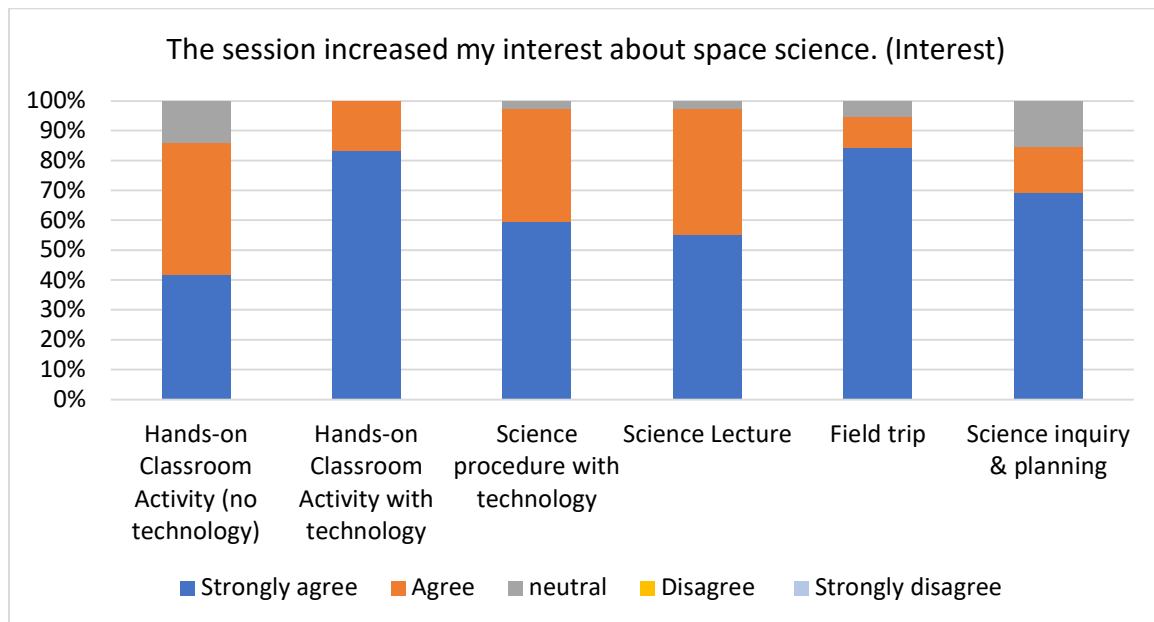


Figure 7. Teacher Perception about Interest depending on session modes

The participants thought that field trip and hands-on classroom activity with technology integration session increased the most their interest about space science (Figure 8).

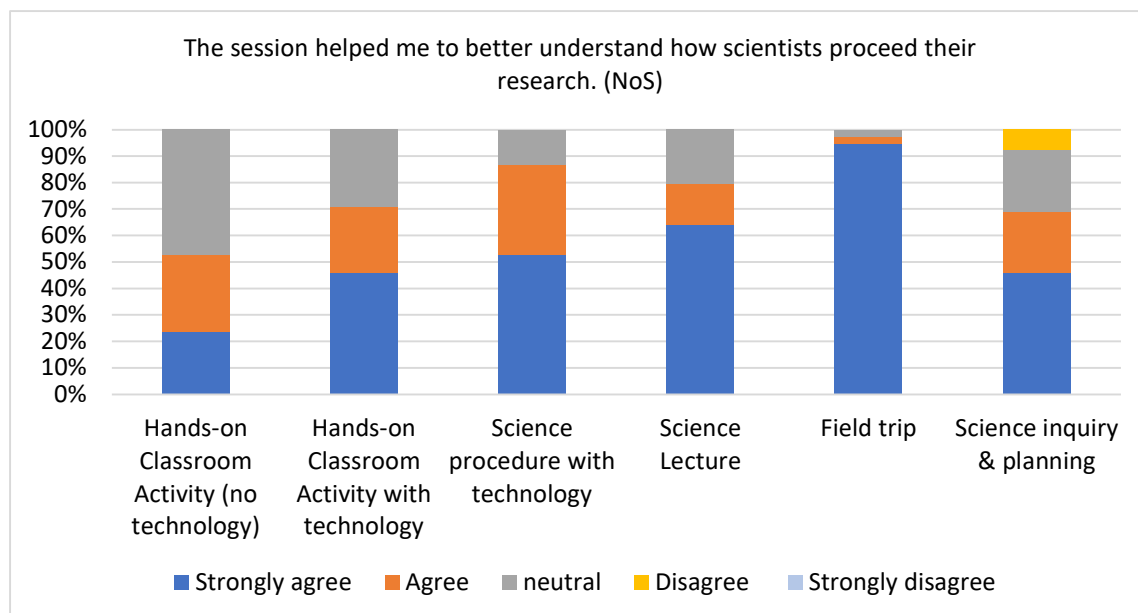


Figure 8. Teacher Perception about Nature of Science depending on session modes

The nature of science was the most recognized at the field trip (Figure 9). Both keynote science lecture and science data procedure with technology session also helped them better understand the nature of science.

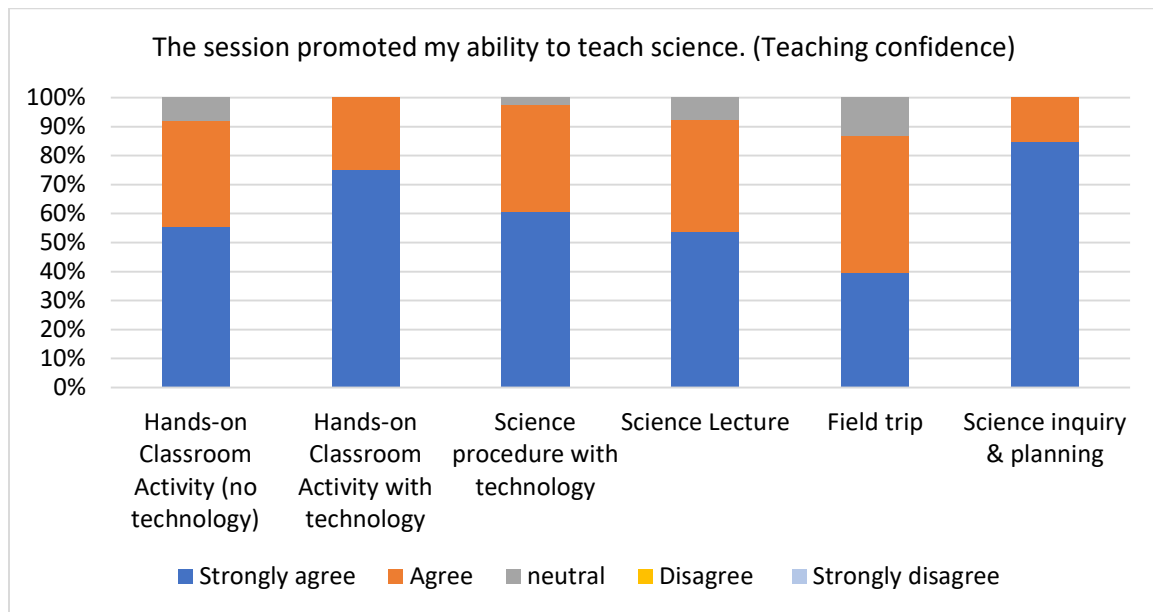


Figure 9. Teacher Perception about Teaching Confidence depending on session modes

The participants thought that science inquiry & planning sessions promoted their ability to teach science the most. They thought that hands-on classroom activity with technology integration session increased their teaching ability as the second most (Figure 10).

These Likert data results gave some general ideas about the participants' perceptions of what may have affected on which. Their thoughts about their learning experience at each PD mode were further investigated in the open-ended questions.

## C.2. Open-Ended Response Result: Thoughts about Sessions

Each day, the participants asked to describe how they thought each session was beneficial to them (if not, what to improve). The participants' responses are summarized below by session mode.

### C.2.1. Hands-on Classroom Activity (no technology integration)

Categories	Exemplary quotes
Getting pedagogical ideas	<p>• <b><u>about using questions in class discussion</u></b></p> <p>"Great when one set can be used with different questions" (ID: 11123, Scale Activity)</p> <p>"This made me think about questions to learn more" (ID: 57910, Scale Activity)</p> <p>"Easy to use, high interest. Generated great questions." (ID: 71901, Scale Activity)</p>

	<p><i>"Fun, high interest. I could see this as great leading questions for a class discussion" (ID: 71901, Light &amp; Color Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>about how to teach the concept better</u></b></li> </ul> <p><i>"Helpful to explain concepts of astronomy to students" (ID: 1119L, Scale Activity)</i></p> <p><i>"Yes, this session was beneficial because it showed how important it is to perceive scale correctly, which is not straightforward." (ID: 33022, Scale Activity)</i></p> <p><i>"I love light and the activity helped me think of how to help kids use spectrometers to learn about it" (ID: 44750, Light &amp; Color Activity)</i></p> <p><i>"I had never really actually figured out how to visualize or explain this concept before - I have a much better understanding now and will bring this to my students" (ID: LPAGE, SEM Model Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>Formative Assessment</u></b></li> </ul> <p><i>"Useful formative assessment that is image heavy but not text to inspire thinking" (ID: D1774, Scale Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>about using models</u></b></li> </ul> <p><i>"It was interesting to think about how to implement modeling with students. I liked how we could use the same model for lots of phenomena." (ID: 44750, SEM Model Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>Way to address Misconceptions</u></b></li> </ul> <p><i>"Useful manipulatives and how to address misconceptions by students" (ID: 82666, SEM Model Activity)</i></p>
Interactive and fun	<p><i>"I was familiar with it but it was still informative and engaging. I love those lessons!" (ID: 44750, Scale Activity)</i></p> <p><i>"Yes. It was interactive, fun, and provided good tips for lessons with this idea" (ID: 33022, Light &amp; Color Activity)</i></p>
Getting to understand concepts better	<p><i>"Very informative, I found the activity helpful for understanding a difficult concept in a concrete way" (ID: 88337, Light &amp; Color Activity)</i></p> <p><i>"Yes- helped me recall how light works. Love the filters and the demo with IR remote" (ID: LPAGE, Light &amp; Color Activity)</i></p>
Increase student understanding	<p><i>"Great session. The information and the modeling are great ways to increase student understanding. I plan to use the ideas in class next year" (ID: 13021, SEM Model Activity)</i></p> <p><i>"Excellent activity to simulate thinking and communication" (ID: 33027, SEM Model Activity)</i></p>
Implementation into class	<ul style="list-style-type: none"> <li>• <b><u>easy setup</u></b></li> </ul> <p><i>"Yes! This was a rich activity with an easy setup (cards). I liked that it was somewhat open to interpretation" (ID: L2578, Scale Activity)</i></p> <p><i>"This was beneficial b/c it was a great demo that can be created with little material and setup" (ID: 13021, Light &amp; Color Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>easy to implement</u></b></li> </ul> <p><i>"Great, easy to implement activity. I can see myself doing this exact activity with my class" (ID: 88337, Scale Activity)</i></p> <p><i>"The lesson structure is something I can use in all my classes." (ID: Lucky, SEM Model Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>plan to implement</u></b></li> </ul>

	<p><i>"Yes! Thank you for the color filters- this will save so much time. I am thinking about how I will apply this in the classroom." (ID: :2578, Light &amp; Color Activity)</i></p> <p><i>"I still haven't added this topic to my curriculum yet but I need to!" (ID: Lucky, Light &amp; Color Activity)</i></p> <p><i>"The model is excellent and I will definitely be using it in my classroom" (ID: 88331, Light &amp; Color Activity)</i></p>
Sharing and Collaboration	<p><i>"This was a great experience. It really got us to fully explain our thinking and to work with other participants" (ID: 71901, SEM Model Activity)</i></p> <p><i>"Yes!! This is such a tough concept for kids to learn! This model (from Carolina) lends itself to detailed study at many levels. It also gives kids a chance to work together and explain models together" (ID: L2578, SEM Model Activity)</i></p>
Comments	<ul style="list-style-type: none"> <li>• <b><u>The session was long or slow</u></b></li> </ul> <p><i>"Interacting with resources that I can keep!, collaboration with other science teachers, too long" (ID: LOLA1, Scale Activity)</i></p> <p><i>"Yes- liked the multiple iterations and the questions that allows. Could have been faster/tighter and/or had more discussion as whole group on each round" (ID: LPAGE, Scale Activity)</i></p> <p><i>"Interesting display, didn't seem organized/practiced for this space." (ID: 11123, Light &amp; Color Activity)</i></p> <p><i>"interesting demo but needs to be managed with the space to keep kids/students involved, ex: have students help create graphs. Have modeling time" (ID: D1774, Light &amp; Color Activity)</i></p> <ul style="list-style-type: none"> <li>• <b><u>Challenging</u></b></li> </ul> <p><i>"This was a challenging session. I came away with more questions than understandings" (ID: 57910, SEM Model Activity)</i></p>

### C.2.2. Hands-on Classroom Activity with Technology Integration

Categories	Exemplary quotes
Getting pedagogical ideas	<ul style="list-style-type: none"> <li>• <b><u>about how to teach the concept better</u></b></li> </ul> <p><i>"Excellent! An easy approach to a topic that requires children to think outside of the box and use actual data to understand how and why we have seasons" (ID: 33027, WWT)</i></p> <p><i>"Great ideas, I currently do not teach seasons but I have a lot of ideas about how I can adjust some of these ideas for my moon phase unit" (ID: 88337, WWT)</i></p> <p><i>"Yes! The combinations of kinesthetic, visual/spatial, low/high tech is just right- and the intentional sequencing to build conceptual understanding and reveal misconceptions is exactly what I've needed for years, I understand much better now, and have great ideas for classroom implementation" (ID: LPAGE, WWT)</i></p> <p><i>"Yes; looking at building up knowledge on seasons, especially with sun's path, calculating position at different times and having the video resource as a check" (ID: 01774, WWT)</i></p> <ul style="list-style-type: none"> <li>• <b><u>about using models</u></b></li> </ul>

	<p><i>"Yes definitely. There was some great ideas on how to model the seasons presented. I love the use of the plastic domes and plan on using them in class" (ID: 13021, WWT)</i></p> <p><i>"Very useful. I love the sun tracker. I have more ideas on how to implement seasons modeling. I am still not totally sure the order of lessons I will use but I am excited." (ID: 44750, WWT)</i></p> <p><i>"Sun plotter for apparent motion to view of Earth related to Earth model with sticky Vicky for actual motion. Point of view activities, useful to ID spatial awareness weakness in students" (ID: 82666, WWT)</i></p>
Getting to understand concepts better	<p><i>"Yes! The combinations of kinesthetic, visual/spatial, low/high tech is just right- and the intentional sequencing to build conceptual understanding and reveal misconceptions is exactly what I've needed for years, I understand much better now, and have great ideas for classroom implementation" (ID: LPAGE, WWT)</i></p> <p><i>"This was really informative" (ID: 57910, WWT)</i></p>
Increase student understanding	<p><i>"I loved viewing the archives of astronomical plates, the lesson videos were great and I am sure the students will learn from them" (ID: 1119L, WWT)</i></p> <p><i>"This was so amazing. It is an opportunity to have children see things they might not have been able to see." (ID: 57910, WWT)</i></p>
Implementation into class	<ul style="list-style-type: none"> <li>• <b><u>easy to implement</u></b></li> </ul> <p><i>"Yes! I don't teach seasons but there are many components of the unit that are extremely helpful- the animations, interactive quality of the internet site, etc.; what a treat to be given supplies that are ready to be used in the classroom" (ID: L2578, WWT)</i></p> <ul style="list-style-type: none"> <li>• <b><u>plan to implement</u></b></li> </ul> <p><i>"Very beneficial- I will be using much of this unit in my classroom and will share with colleagues" (ID: 71901, WWT)</i></p> <p><i>"This was great information I can definitely use this in class and I think it will really help students visualize" (ID: 13021, WWT)</i></p> <p><i>"This model and the videos were awesome!! Even though It's for gr 6-8 I will definitely use with my 12th grade class" (ID: Lucky, WWT)</i></p>
Getting useful resources and learning to use a tool	<p><i>"examining how to use the website and many of the tools introduced to help students explore" (ID: 01774, WWT)</i></p> <p><i>"Great tool for students and teachers alike." (ID: 33027, WWT)</i></p> <p><i>"This is a powerful tool and I'm glad I got an opportunity to begin to work with it. I will be spending time exploring the tools this summer" (ID: 71901, WWT)</i></p> <p><i>"Yes! This is a great resource for the classroom! Being able to rotate the view of objects will be so helpful (and speeding up/slowing down movement)" (ID: L2578, WWT)</i></p>
Becoming comfortable using a software	<p><i>"I enjoyed using WWT and I feel more confident using the software now both as myself and with my classes" (ID: 88331, WWT)</i></p> <p><i>"Becoming comfortable with all of the basic functions was really helpful and makes me more likely to use it on my own with my kids. So many cool visualizations - I can see turning kids loose to explore + lesson ideas!" (ID: Lpage, WWT)</i></p>

### C.2.3. Science Data Procedure with Technology Integration

Categories	Exemplary quotes
Getting pedagogical ideas	<ul style="list-style-type: none"> <li>• <b><u>about how to teach the concept better</u></b></li> </ul> <p>"I will use the Blink feature in my class! Using RGB mode to color code other wavelengths will be a great way to emphasize the x-ray, w, and IR forms of light too" (ID: Lucky, MicroObs3)</p>
Interactive and fun	<p>"Enjoyed hands-on approach to image processing. Activity valuable for students to produce a personal product" (ID: 82666, MicroObs1)</p> <p>"very cool and student friendly" (ID: 88337, MicroObs1)</p> <p>"This was fun, I think my students would be engaged by this!" (ID: Lucky, MicroObs1)</p>
Getting to understand concepts better	<p>"Love the telescope activity (kinesthetic). I understand reflecting telescopes now" (ID: 44750, MicroObs2)</p> <p>"loved the physical telescope kinesthetic model" (ID: Lpage, MicroObs2)</p>
Implementation into class	<ul style="list-style-type: none"> <li>• <b><u>plan to implement</u></b></li> </ul> <p>"I love doing the image processing! I will include it in my course." (ID: Lucky, MicroObs2)</p> <p>"Yes. It was good to see how to calibrate and combine the images. The value of combining the different filters was obvious and I plan to do that with my students." (ID: 13021, MicroObs2)</p> <p>"This program is awesome! I love it and I can't wait until I can use it with my students" (ID: 88337, MicroObs3)</p> <p>"Useful once again to utilize tools of image editing and design, put final thoughts of how M.O. could be used with students" (ID: 01774, MicroObs3)</p> <ul style="list-style-type: none"> <li>• <b><u>needs modification before implementing</u></b></li> </ul> <p>"useful as potential activity with students, needs to be carefully tailored to attain specific objectives" (ID: D1774, MicroObs1)</p> <p>"Yes! Still learning how to use this well. I'm not sure how I will use it in the classroom yet." (ID: L2578, MicroObs1)</p>
Getting useful resources and learning to use a tool	<p>"Great intro to a powerful tool. It was great to have time to "play" with the software." (ID: 71901, MicroObs1)</p> <p>"Very useful each time we learn more about the Microobservatory. I feel like we could spend the whole week on just that and still have more to learn" (ID: 13021, MicroObs3)</p> <p>"Helpful to get more time to work with the software- frustrating at times, but I really like the available curriculum" (ID: 71901, MicroObs2)</p> <p>"Image editing process + using the Youth network for students to access and use the resource --&gt; helpful as a start" (ID: 01774, MicroObs2)</p> <p>"Model of youth astronnet portal useful." (ID: 82666, MicroObs2)</p> <ul style="list-style-type: none"> <li>• <b><u>Networking</u></b></li> </ul> <p>"CfA Education forums are a great way to connect students w/ hands on learning, teachers, and scientists" (ID: LOLA1, MicroObs2)</p>
Becoming comfortable using a software	<p>"I'm getting better with using this tool- its been a good exercise in working through frustration!" (ID: 71901, MicroObs3)</p>



	<p><i>"I am really enjoying using this program and I am gaining confidence in producing images. I also appreciate the student interface option" (ID: 88337, MicroObs2)</i></p> <p><i>"Yes! This session all the pieces came together and I felt more confident using it" (ID: Lpage, MicroObs3)</i></p>
Having the real world (professional science?) experience	<p><i>"Yes! I think it will be empowering for students to request their own images from the telescope" (ID: L2578, MicroObs2)</i></p> <p><i>"Yes. Real audience for our work (submitting to NASA photo contest)" (ID: L2578, MicroObs3)</i></p> <p><i>"Yes! Loved entering a challenge w/ images we processed" (ID: LOLA1, MicroObs3)</i></p>

#### C.2.4. Science Lecture by Distinguished Scholars

Categories	Exemplary quotes
Enthusiastic & Inspiring	<p><i>"Hearing the importance of finding misconceptions and including these on assessments. Presenter's enthusiasm was wonderful! :)" (ID: 11123, AstroMiscon)</i></p> <p><i>"Yes. It was such a pleasure to hear Dr. Geller speak and to hear her perspectives as a woman scientist. Her story of how she chose astrophysics is one that impressed me." (ID: 13021, MapUniverse)</i></p> <p><i>"Amazing guest speaker. That was a real treat. Dr. Gellar is an inspiring speaker." (ID: 71901, MapUniverse)</i></p> <p><i>"Amazing, favorite of the whole week" (ID: 57910, MapUniverse)</i></p> <p><i>"I enjoyed an obviously intelligent, hardworking, and successful scientist" (ID: 1119L, MapUniverse)</i></p> <p><i>"Yes. The talk was very inspiring- especially since she was a woman in a male-dominated field of science" (ID: L2578, MapUniverse)</i></p> <p><i>"Very informative and great speech with dynamic presence" (ID: 01774, MapUniverse)</i></p> <p><i>"Awesome to hear from a distinguished scientist!" (ID: LOLA1, MapUniverse)</i></p> <p><i>"The presentation was amazing. I learned so much about astronomy research, Dr. Margaret Gellar's discoveries, her perspectives and insights on her career path" (ID: Lucky, MapUniverse)</i></p>
Getting to hear professional knowledge	<p><i>"Outstanding presentation that provided insights on how children interpret data and graphical images" (ID: 33022, AstroMiscon)</i></p> <p><i>"This brought me back to early grad school- great to hear from the source. Excellent points brought up" (ID: 71901, AstroMiscon)</i></p> <p><i>"Yes- the power of misconceptions is scarily impressive. Wish it had included more specific examples of how to reset/break/shift misconceptions" (ID: Lpage, AstroMiscon)</i></p> <p><i>"Impressive presentation with high value" (ID: 33027, MapUniverse)</i></p> <p><i>"Well knowledge and accomplished speaker." (ID: 82666, MapUniverse)</i></p>
Getting pedagogical ideas	<p><i>"Pedagogy helpful for testing" (ID: 1119L, AstroMiscon)</i></p> <ul style="list-style-type: none"> <li>• <b><u>about how to teach the concept better</u></b></li> </ul>

	<p><i>"This was so beneficial. I learned a great deal about how I can help my children I teach" (ID: 57910, AstroMiscon)</i></p> <p>• <b><u>Way to address Misconceptions</u></b></p> <p><i>"soooo informative. It gave me the resolve to learn even more about common student misconceptions" (ID: 44750, AstroMiscon)</i></p> <p><i>"Liked data graphs by grade regarding misconceptions between teacher + students" (ID: 82666, AstroMiscon)</i></p> <p><i>"Yes! I usually skim the topic of scale, but perhaps I need to address it further" (ID: L2578, AstroMiscon)</i></p> <p><i>"I'm excited by the data and will be researching misconceptions as I put my curriculum together" (ID: Lucky, AstroMiscon)</i></p>
Getting to understand concepts better	<p><i>"Absolutely awesome to be in the presence of a great mind. Learned a ton and very inspired. Never understood red shift before and now I sort of do!" (ID: Lpage, MapUniverse)</i></p> <p><i>"I have had trouble explaining the images of the Universe to students before-now I feel like I understand" (ID: 44750, MapUniverse)</i></p>
Nature of Science - Interdisciplinary	<p><i>"Fantastic! So wonderful to get to hear this presentation. I loved the concept of interdisciplinary science... I hope to take that back to my class" (ID: 88337, MapUniverse)</i></p>

### C.2.5. Field Trips

Categories	Exemplary quotes
Enthusiastic & Inspiring	<p>• <b><u>Enthusiastic Scientists</u></b></p> <p><i>"Meeting scientists was inspiring. Yes, they work hard and sometimes it is tedious but when find something..." (ID: 1119L, Chandra)</i></p> <p><i>"It was wonderful to see dedication." (ID: 1119L, Labs)</i></p> <p><i>"The best was hearing about the archives from someone who is obviously so interested in the history and loves what she does" (ID: 13021, CfA Facilities)</i></p> <p><i>"Great tour. Jonathan's enthusiasm is contagious." (ID: 13021, Chandra)</i></p> <p><i>"Jonathan's enthusiasm is infectious and his knowledge and ability to explain is incredible" (ID: Lucky, Chandra)</i></p> <p><i>"All presenters seems so enthusiastic about what they are doing/contributing" (ID: L2578, Labs)</i></p> <p><i>"It was so cool to see some of the very different projects going on here, and to meet the scientists and see how excited they are about their work" (ID: Lucky, Labs)</i></p> <p>• <b><u>Inspiring</u></b></p> <p><i>"These are the opportunities that keep me inspired and curious so I can inspire my kids" (ID: Lpage, CfA Facilities)</i></p> <p><i>"Awe inspiring + inspirational- I felt like I was stepping into history or a movie. Learned so much + was personally inspired" (ID: Lpage, Chandra)</i></p> <p><i>"It was inspiring and so cool!" (ID: Lucky, Chandra)</i></p> <p><i>"Mind blowing! Thank you for this amazing opportunity." (ID: 33027, Chandra)</i></p> <p><i>"Very cool to get to see this facility. I was so impressed and enjoyed the tour very much!" (ID: 88331, Chandra)</i></p>



	<p><i>"This was amazing it was very exciting to be able to be there and learn from the people who created and continue to work on it" (ID: 57910, Chandra)</i></p> <p><i>"I always love seeing scientists labs and these were particularly fun. So many unique and highly engineered tools! Passionate, interdisciplinary, inspiring" (ID: Lpage, Labs)</i></p> <p>• <b><u>Inspiring Scientific Artifacts</u></b></p> <p><i>"excellent visual + historical display of scientific artifact, very knowledgeable staff" (ID:01774, CfA Facilities)</i></p> <p><i>"Fascinating. Seeing the historical aspect of Astronomy in the great refractor was great." (ID: 13021, CfA Facilities)</i></p> <p><i>"Excellent tours! Thank you for having us! I loved seeing all of the telescopes and can't wait to use the Microobservatory with my students" (ID: 88337, CfA Facilities)</i></p> <p><i>"The old telescope was absolutely fascinating to see." (ID: L2578, CfA Facilities)</i></p>
Interest	<p>• <b><u>Increasing Interest</u></b></p> <p><i>"I loved this tour, I'm now more interested in the history of astronomy as well as the engineering behind the equipment" (ID: Lucky, CfA Facilities)</i></p> <p><i>"Wow- exciting trip! Glad to make the connection with local scientists. I will be following up with this in the fall" (ID: 71901, Chandra)</i></p> <p><i>"Yes! Loved it. The history of the glass plates (and women's involvement) was fascinating and makes me want to read the Glass Universe book." (ID: L2578, CfA Facilities)</i></p>
Having to see the real world (professional science) experiment/ research (or, having to see research in action)	<p><i>"Loved it. It was a great real world experiment. I talk about the deep space network with students and now I have seen it working for myself." (ID: 44750, Chandra)</i></p> <p><i>"It offered a look at the behind the scenes operational telescope and how data are collected in a systematic way" (ID: 33027, Chandra)</i></p> <p><i>"Very interesting and well worth the visit to discuss current science and how the lab answers certain questions" (ID: 01774, Labs)</i></p> <p><i>"Yes. It was impressive to see how much science was going on in just one building. While not all of it was understood, it was fascinating to hear about all the possibilities." (ID: 13021, Labs)</i></p> <p><i>"Real science in real science by real scientists. It takes a village (collaboration) to solve questions." (ID: 33027, Labs)</i></p> <p><i>"Yes. Very interesting to see research in action!" (ID: L2578, Labs)</i></p>
Implementation into class	<p>• <b><u>plan to implement</u></b></p> <p><i>"Yes! This was a fascinating tour/lecture about something I knew nothing about. I would like to incorporate this with my waves unit." (ID: L2578, Chandra)</i></p> <p>• <b><u>connects to science standards</u></b></p> <p><i>"Great to experience and learn about research being done that connects to space standards" (ID: LOLA1, Labs)</i></p>
Getting to hear professional knowledge	<p><i>"excellent academic background shown and presented, good tutorial of Chandra construction, operations, and light collection. Good background on visualization" (ID: 01774, Chandra)</i></p>

	<i>"I loved learning about X-Ray telescopes. Lots of practical information to share with my students when they ask random questions" (ID: 44750, Labs)</i>
Nature of Science - Interdisciplinary	<i>"I really enjoyed this tour. It was so interesting to see the different types of research happening and all of the various disciplines involved." (ID: 71901, Labs)</i> <i>"I always love seeing scientists labs and these were particularly fun. So many unique and highly engineered tools! Passionate, interdisciplinary, inspiring" (ID: Lpage, Labs)</i>
Others - Informative	<ul style="list-style-type: none"> <li>• <b><u>Informative about history in science</u></b>  <i>"Amazing historical perspective that enhanced the importance of archival of historical data to simulate learning and apply it to future scientific research" (ID: 33027, CfA Facilities)</i>  <i>"So cool, every part. Seeing the great refractor felt like stepping into Hogwarts, I love archives, and the microobservations were fun." (ID: Lpage, CfA Facilities)</i>  <i>"Very well organized, I loved everything about the tours. The information was at the right level. The focus on female astronomical history was great." (ID: 44750, CfA Facilities)</i>  <i>"Telescopes, refractors, stacks, so informative" (ID: 57910, CfA Facilities)</i>  <i>"Great historical information, particularly the information about the female scientists. Great tour!" (ID: 71901, CfA Facilities)</i>  <i>"I enjoyed the facilities tour for historical lessons of helping women and early discoveries in astronomy in Boston!!" (ID: 1119L, CfA Facilities)</i> </li> <li>• <b><u>Informative about cutting-edge science research</u></b>  <i>"Fascinating to see + to hear about some of the history of Chandra and its great accomplishments. Including accidental ones." (ID: 13021, Chandra)</i>  <i>"Really informative" (ID: 57910, Labs)</i> </li> </ul>

### C.2.6. Science Inquiry & Planning

Categories	Exemplary quotes
Getting pedagogical ideas	<ul style="list-style-type: none"> <li>• <b><u>about using photos in scientific inquiry</u></b>  <i>"Great review of inquiry and ideas for adding different phenomena to classes" (ID: 88337, Science Inquiry)</i>  <i>"Yes. Reminder that photos and giving students time to observe them can lead to cognitive dissonance" (ID: L2578, Science Inquiry)</i>  <i>"Yes! Great examples of using images for discrepant events" (ID: LOLA1, Science Inquiry)</i>  <i>"Yes! I often start with a visual phenomenon, but didn't have the spectrum framework to know why" (ID: Lpage, Science Inquiry)</i>  <i>"Photos are easy to find, I love the idea of using them to drive inquiry!" (ID: Lucky, Science Inquiry)</i>  <i>"This session was helpful in framing my thinking on concrete/abstract reasoning" (ID: 71901, Science Inquiry)</i> </li> <li>• <b><u>in designing a lesson of introducing a new concept</u></b>  <i>"Thought provoking and helpful in terms of design of lessons and introduction of new concepts to students" (ID: 01774, Science Inquiry)</i> </li> </ul>

Implementation into class	<ul style="list-style-type: none"> <li>• <b><u>plan to implement</u></b>  <i>"The session was useful. I like the idea of using photos and will experiment with using them as a warm up to the day's lesson" (ID: 13021, Science Inquiry)</i>  <i>"Excellent source of ideas to bring to the classroom/to implement in the classroom to get the students fully engaged" (ID: 33027, Planning Time)</i>  <i>"This time was super productive for us, I am excited to try this out with students!" (ID: Lucky, Planning Time)</i> </li> </ul>
Nature of Science - Scientific method	<ul style="list-style-type: none"> <li>• <b><u>reflection to digest learning</u></b>  <i>"Good didactic scheme on how scientists work" (ID: 33027, Science Inquiry)</i> </li> </ul>
Sharing and Collaboration	<ul style="list-style-type: none"> <li>• <b><u>reflection to digest learning</u></b>  <i>"Challenging, but fun to put all ideas from the week to reflect and think of how they might be put into effect in the classroom" (ID: 01774, Planning Time)</i>  <i>"The planning time was great for being able to plan and process some of the information in a more concrete way" (ID: 13021, Planning Time)</i>  <i>"soooo important to give reflection time and see everyone else's ideas" (ID: 44750, Planning Time)</i>  <i>"Yes! Thinking back over everything we've done this week was helpful, as was some preliminary curriculum planning time. Very inspiring seeing others ideas too" (ID: Lpage, Planning Time)</i>  <i>"Yes. Great visual of what we learned today, chance to ask questions, make comments, draw connections" (ID: L2578, Planning Time)</i> </li> <li>• <b><u>sharing ideas</u></b>  <i>"So great to see all of the other teachers ideas- have time to share observations, questions" (ID: 71901, Planning Time)</i>  <i>"Good to share how we will employ in classrooms" (ID: 82666, Planning Time)</i>  <i>"So great to see what others have done to implement from this and great to get to start planning" (ID: 88337, Planning Time)</i>  <i>"I was impressed with how well everyone did, that could only happen because of careful organization" (ID: 1119L, Planning Time)</i>  <i>"Yes! Loved making the poster + sharing out. Great closing." (ID: LOLA1, Planning Time)</i>  <i>"open discussion w/ presenters and participants" (ID: 02472, Science Inquiry)</i>  <i>"time to think + share" (ID: 11123, Planning Time)</i> </li> </ul>

### C.3. Open-Ended Response Result: Thoughts about key take-aways

The participants were asked to write about key take-aways of the day. Their responses are summarized below.

Categories	Exemplary Quotes
Pedagogical ideas	<ul style="list-style-type: none"> <li>• <b><u>Investigating student misconceptions</u></b>  <i>"have students write ideas/misconceptions to reflect back on after" (ID: 11123, Mon)</i>  <i>"way to better ensure that students gain correct ideas for astronomy concepts" (ID: 1119L, Mon)</i> </li> </ul>

*"I am going to make sure I know about the misconceptions that children bring about the subjects knowledge I teach." (ID: 57910, Mon)*

*"I will use the information from the misconception session to examine my practices, and will share with colleagues" (ID: 71901, Mon)*

*"will be thinking about how to discover student misconceptions" (ID: L2578, Mon)*

*"importance of understanding student misconceptions," (ID: Lucky, Mon)*

**• Student Assessment**

*"logistics to address student teacher misconceptions to improve scoring by students" (ID: 82666, Mon)*

*"Solid ideas for pre/post probes" (ID: 01774, Mon)*

*"perspective taking formative assessments, sun tracker modeling, worldwide telescope- especially lesson 7! That looks great!" (ID: 44750, Tue)*

**• Using models & resources**

*"looking at data viz with both tech and analog models, approaching lessons w/ common misconceptions in mind, thinking about student exploration + understanding with digital resources" (ID: 01774, Tue)*

*"Using the planet dome is a must. The World Wide telescope is also a must" (ID: 13021, Tue)*

*"historical perspective, use of 3D models to understand key concepts, find out what misconceptions children may have about certain concepts before starting a lesson" (ID: 33027, Tue)*

*"I will definitely use the modeling techniques/videos and lessons from the seasons lesson." (ID: 71901, Tue)*

*"So many! Sticky Vicky will make a comeback this fall- what a great strategy for teaching perspective. The ThinkSpace seasons session has helpful animations, etc. to assist in teaching day/night. Models (sun, Earth on stick) are very helpful. I thought about more misconceptions kids might have" (ID: L2578, Tue)*

*"data viz tools!, misconceptions- need to intentionally review and plan for, solar model - yes and yes!!" (ID: Lpage, Tue)*

*"The sun tracker will be so helpful! I also want to incorporate the story of the glass plates of the computers" (ID: Lucky, Tue)*

*"Using tech resources to promote exploration or challenging ideas, using modeling to promote understanding and perspective, bring current actor-research + database to the classroom" (ID: 01774, Wed)*

*"Good to state shortcomings of web + desktop worldwide telescope and that (web) was a project in progress, Hands on activities, T format documentation similar to engineering + design process" (ID: 82666, Wed)*

*"I like the structure of the Sun-Earth-Moon activity and will be adapting my other lessons to fit the format. I hope the students enjoy WWT as much as I do!" (ID: Lucky, Wed)*

**• managing & facilitating student ideas**

*"How to use modeling activities with students: how to manage it, how to facilitate student thinking, the benefits of using an open ended model, deep space network: how it works, I also like how the world wide telescope can superimpose telescope images" (ID: 44750, Wed)*

**• Using visuals (photos of phenomena) into scientific inquiry**



	<p><i>"Thinking about visuals in the 4 part model (concrete/abstract) and how the visual can part of the lesson design, collecting thoughts on resources and how they might fit into a unit or multiple lessons" (ID: 01774, Fri)</i></p> <p><i>"Starting w/ a concrete model and moving to the abstract, pictures visual representation of "midnight sun"" (ID: 02472, Fri)</i></p> <p><i>"I will use the concept of bringing real photos into class to help increase understanding and make connections." (ID: 13021, Fri)</i></p> <p><i>"lion/zebra vs bee/flower picture" (ID: 44750, Fri)</i></p> <p><i>"The use of a photo to create cognitive dissonance," (ID: L2578, Fri)</i></p> <p><i>"To drive inquiry (it doesn't always have to take a lot of setup!) and it will be easy to incorporate inquiry more frequently" (ID: Lucky, Fri)</i></p>
Science History	<p><i>"I would also love to include some more science history like we learned on our observatory tour" (ID: 88337, Tue)</i></p> <p><i>"historical perspective," (ID: 33027, Tue)</i></p>
Field Trip place	<p><i>"possible field trip to plates archive" (ID: Lpage, Tue)</i></p> <p><i>"I will try to set up a field trip to Chandra in Burlington to supplement my astronomy unit!" (ID: LOLA1, Wed)</i></p>
Hands-on activity &/or demonstration	<p><i>"light color demo, using the Microobservatory" (ID: 13021, Mon)</i></p> <p><i>"I will definitely include the scale activity and Microobservatory lessons in my classroom." (ID: 71901, Mon)</i></p> <p><i>"I will absolutely be adding the scale activity and Microobservatory activates and will be using the concept of the color and light in some way" (ID: 88337, Mon)</i></p> <p><i>"image processing from Archive images, how old/big/far card sort, waves content" (ID: Lpage, Mon)</i></p> <p><i>"I would like to use/adjust from WWT to use in my moon phase unit. I am particularly interested in seeing if I could adjust the clear dome activity to be used in understanding the moon phases." (ID: 88337, Tue)</i></p> <p><i>"Everything! Sun- moon- Earth from Carolina to show moon phases, eclipses, orbits (planes of), rotate earth to show path of moon's shadow on Earth, why lunar and solar eclipses happen within 2 weeks of each other, etc., WWT to show organization of solar system -&gt; galaxy --&gt; universe" (ID: L2578, Wed)</i></p>
Getting to understand concepts better	<p><i>"I don't have time for Microobservatory unfortunately but using it myself has given me a better understanding of telescopes and astronomy imaging. I hope to bring this understanding to my students." (ID: 44750, Thur)</i></p> <p><i>"So many! Gravity, universe structure and patterns" (ID: Lpage, Thur)</i></p>
Science data procedure	<p><i>"How to set images from a telescope and highlight what we can see into images. I would highlight the importance of all subjects we learn to apply it to everyday science and life." (ID: 33027, Thur)</i></p>
Ideas for student research	<p><i>"for connecting to citizen science/student research, tech + software to model concepts" (ID: 01774, Mon)</i></p> <p><i>"image request and analysis/processing-not quite sure how yet, but good ideas." (ID: Lpage, Mon)</i></p> <p><i>"I have some ideas for projects students can do using it. I will use ideas from Jonathan's presentation to help teach the electromagnetic spectrum in my freshman phys. sci classes." (ID: Lucky, Wed)</i></p>



	<i>"Using Microobservatory for student observations and w/ image processing --&gt; possible student research" (ID: 01774, Thur)</i>
Nature of Science	<ul style="list-style-type: none"> <li>• <b><u>Scientists</u></b>  <i>"seeing what scientists are doing right now in the lab/field" (ID: 01774, Thur)</i>  <i>"I will definitely talk about Dr. Geller and her history- students should learn about her. I will discuss the various types of research I observed, and I will try to get more scientists in to talk to my students." (ID: 71901, Thur)</i>  <i>"I am inspired to get more guest speakers to my school if possible. Students can get the opportunity to interact with experts in the field" (ID: L2578, Thur)</i>  <i>"I will definitely schedule a Skype Q&amp;A with a scientist for my class through the CfA portal" (ID: LOLA1, Thur)</i> </li> <li>• <b><u>Collaboration &amp; Interdisciplinary in Science Research</u></b>  <i>"There is lots more to learn. It is very important that scientists from many disciplines and countries collaborate to continue to make decisions about us, Earth, and the Universe" (ID: 1119L, Thur)</i>  <i>"kinesthetic telescope!, image processing's on JS9, poetry activity, interdisciplinary science" (ID: Lucky, Thur)</i> </li> <li>• <b><u>Science in action</u></b>  <i>"So many! Gravity, universe structure and patterns - cross cutting concepts! Science in action" (ID: Lpage, Thur)</i> </li> </ul>

#### C.4. Suggestions & Comments about the Program

Categories	Quotes
More time for hands-on activities/or faster pace	<i>"More time for additional hands on activities" (ID 33022, Mon)</i> <i>"Logistically, the sessions were a little choppy- I think the keynote (misconceptions) may have been better at the beginning or end" (ID 71901, Mon)</i> <i>"The content is really interesting but sometimes the pace of the session seems to drag. I'd love if the sessions felt more urgent! Thanks! :)" (ID: LPLA1, Mon)</i> <i>"A lot was planned it felt very rushed but I got a lot out of it! I'm sorry I don't remember the scale activity" (ID: Lucky, Mon)</i>
Time to digest	<i>"Overloaded a bit. Need time to decompress. Could have been overloaded more without background knowledge" (ID: 82666, Tue)</i>
Step-by-step guidance (for how to use technology)	<i>"I like step by step guides, like a formula. That would enable use of computer to be easier and more fun." (ID: 1119L, Wed)</i> <i>"Specific agenda/written instructions for using microbservators, having basic steps laid out for editing tools advanced steps" (ID: 01774, Thur)</i> <i>"Provide guides with step by step procedures to get images and manipulate them. In this way, we can always have a handy resource to go back to that would indicate all the steps we need to take. :)" (ID: 33027, Thur)</i> <i>"Directory for where locations of Youth Astronomy Portal to be found" (ID: 82666, Thur)</i>
Background information about labs	<i>"Maybe a little more background about the labs before we visit them" (ID: L2578, Thur)</i> <i>"would love to either see all labs or choose 2-3 from a menu of personal interest, maybe a brief overview or diagram before to have context before going to the lab"</i>



	<i>tour?, They're on the website, but maybe task cards or handouts for basic image processing tasks for the microbs. photos?" (ID: Lpage, Thur)</i>
More time on planning	<i>"We could have used more time for the planning" (ID: 13021, Fri)</i> <i>"I would assign the implementation and planning time as a homework activity to have enough time to reflect and bring a poster to share with the other teachers :)" (ID: 33027, Fri)</i> <i>"More time for posters :)" (ID: LOLA1, Fri)</i>
More examples	<i>"More examples of discrepant events in Space science" (ID: L2578, Fri)</i> <i>"Today was great! I'm sad that its ending, thank you all so much!" (ID: Lucky, Fri)</i>
Survey format	<i>"I'd be happy to fill out all surveys virtually. Thank you!" (ID: LOLA1, overall)</i>
Others	<i>"Well planned and executed with lesson and with tours" (ID: 01774, Tue)</i> <i>"The food is so good!" (ID: 57910, Tue)</i> <i>"Everything was great. I really enjoyed today's sessions. Thank you!" (ID: Lucky, Tue)</i> <i>"I learned a lot! It's helpful to experience a lesson as a student and get fresh ideas for my own teaching" (ID: Lucky, Wed)</i> <i>"it was all great!" (ID: Lpage, Wed)</i> <i>"To be honest, I wish this had been a 2 week program...I have loved this program and wish we could spend more time with so many topics. Thanks!" (ID: 88337, Thur)</i> <i>"It was helpful to have parking! Thanks for spoiling us: supplies, activities printed + online, lunch" (ID: 11123, Fri)</i>

## D. Teachers' Perceptions about Physical and Social Contexts of PD

### D.1. Thoughts about the physical context in Learning

The participants were asked how they thought their learning may have affected by the physical context of the academy. The themes that emerged from their responses are summarized below.

#### **First-hand experience is more memorable & that can be more brought to students**

*"fantastic to see in person. It will allow me to speak to students about 1st hand experience." "they will allow for more personal stories talking about 1st hand experience" (ID: 13021, CfA Old Observatory)*  
*"I hope that both of these locations will help me inspire students as to what is possible for them in the field of science" (ID: 88337, Chandra)*

If no physical visit: *"Absence of human connection, loss of memory associated with those experiences, wouldn't be able to share that excitement with my students" (ID: 01774)*

If no physical visit: *"It would not have been as interesting or memorable if I had not had access to the physical space. It drive my enthusiasm as a science teacher to be in spaces where research is happening" (ID: Lola1)*

#### **Feeling more connected**

- *Feeling more connected to the real field*

*"It was great to see the glass slides - gave a real sense of the scope" (ID: 71901, CfA Old Observatory)*

*"Being in the space helps you feel more connected" (ID: Lola1, CfA Old Observatory)*

*"Connecting content to real/current research in the field" (ID: 01774, Research Labs)*

- *Feeling like in different time*

*"Magical- the old observatory was like going back in time." (ID: L2578, CfA Old Observatory)*



*"Felt like I was walking in the shoes of the past "greats" - stepping into Hogwarts. Magical!" (ID: Lpage, CfA Old Observatory)*  
*"I love putting stories to concepts, and these local sites are full of great stories + history connections that make the science come alive. Puts rest in context" (ID: Lpage, CfA Old Observatory)*

- *Feeling like in movies*

*"Wow" - almost unreal- felt like I was in a "Star Trek" movie. So cool" (ID: Lpage, Chandra)*  
*"Beautiful new facility. I don't think I would ever have an opportunity to go to a place like that...it's like from a movie!" (ID: 88337, Chandra)*

### **Rich Experience by the Academic & Historic Atmosphere**

*"Collegiate atmosphere, rich in history and knowledge" (ID: 33027, CfA Old Observatory)*  
*"Well rounded, able to visually explore besides listen to lecture" (ID: 82666, CfA Old Observatory)*  
If no physical visit: *"The visits were so much better -- no way to really get a sense of the slides, or the refractor, just from reading about the sights/smells/sounds." (ID: 71901)*  
If no physical visit: *"The tours made everything much more vivid and immediate" (ID: Lucky)*

### **Excitement & Inspiring**

*"I feel lucky and excited to share with kids" (ID: 57910, CfA Old Observatory)*  
*"Really interesting. The great refractor was so impressive in person" (ID: 71901, CfA Old Observatory)*  
*"I got the chills being in the space where so much of modern astronomy started" (ID: Lucky, CfA Old Observatory)*  
*"Inspirational and awe-inspiring!" (ID: 02472, Chandra)*  
*"Impressive facility, lots of technology needed for monitoring and data retrieved" (ID: 13021, Chandra)*  
*"I was in awe of the expertise of scientists, this place was super cool" (ID: Lucky, Chandra)*  
If no physical visit: *"I think it would be less impactful, there is a big difference seeing things in real life" (ID: 88337)*  
If no physical visit: *"There's just no substitute for actually visiting places. Reading about the old observatory would be dull, I might not understand what Chandra actually does, I would not be as inspired by the glass plates and their history" (ID: L2578) – dual code*

### **Learn Better**

*"to learn and remember it better. I'll never forget the experiences I had this week!" (ID: Lola1, Chandra)*  
If no physical visit: *"I would remember very little" (ID: 44750)*  
If no physical visit: *"There's just no substitute for actually visiting places. Reading about the old observatory would be dull, I might not understand what Chandra actually does, I would not be as inspired by the glass plates and their history" (ID: L2578)*

### **Meeting the real people**

*"Lots of equipment that was too complicated to understand. People who are very excited about what they do" (ID: 13021, Research Labs)*  
*"gas tanks, tubes, metal, etc. Al foil! Busy, but enthusiastic workers" (ID: L2578, Research Labs)*  
*"contextualizes disciplines + their interconnections. Human faces behind cutting edge science" (ID: Lpage, Research Labs)*

- *Nature of Science?*



*"Friendly atmosphere filled with cooperation and humanity" (ID: 33027, Research Labs)*  
*"So great- the scientists working were so gracious and patient" (ID: 71901, Research Labs)*  
*"Science is a field of discovery, failure is expected but to continue to succeed eventually occurs over time" (ID: 82666, Research Labs)*  
*"In a space that had highly driven + focused scientists who were extremely caring" (ID: Lola1, Research Labs)*  
*"Emphasized how a discovery can lead to many applications" (ID: Lucky, Research Labs)*  
*"How humans are still needed to do scientific research" (ID: 33027, Chandra)*  
*"perspective on obstacles + historical challenges for collecting data" (ID: 01774, CfA Old Observatory)*  
*"Emphasize importance of the historical context, how much the way research is done has changed" (ID: Lucky, CfA Old Observatory)*

- *Data Procedure*

*"Exciting to see how the data is collected and monitored" (ID: 01774, Chandra)*

## **D.2. Thoughts about the social context in Learning**

The participants were asked how they thought their learning may have affected by the social context of the academy. The themes by their responses are summarized below.

### **Excitement & Inspiring**

*"Inspired that women could do this" (ID: 11191, Keynote)*  
*"learning from "masters"- such an honor." (ID: Lpage, Keynote)*  
*"It inspires me to try new things in the classroom- materials + approaches." (ID: L2578, Other Participants)*  
 If no social interaction: *"I would have been less exciting and inspirational" (ID: 11191)*

### **Interest & Motivation**

*"I really enjoyed talking with Margaret Gellar. She is an excellent speaker. I am more excited to learn more about the map of the Universe." (ID: 71901, Keynote)*  
*"He brought out a sense of wonder about black holes." (ID: 02472, Field Trip Scientists)*  
*"very helpful, informed, approachable- I was more willing to participate!!!" (ID: L2578, Science Educators)*  
 If no social interaction: *"I do not think I would have enjoyed the class as much as I have." (ID: 88337)*  
 If no social interaction: *"I would have felt isolated and less interested. I would not have felt the community like I have gained this week" (ID: Lola1)*  
 If no social interaction: *"boring + ineffective" (ID: Lpage)*

### **Decreasing the Gap (Feeling more connected)**

*"It's exciting to tell my students about who I've met and what they've accomplished, fewer degrees of separation" (ID: Lola1, Keynote)*

### **Networking**

*"Great interactions with scientists in the field, so helpful to hear them describe their research. I will absolutely try to get more connections to real science for my students- site visits, skype, etc." (ID: 71901, Field Trip Scientists)*  
*"I made connections that I hope to call upon in the future to set up field trips!" (ID: Lola1, Field Trip Scientists)*

*"Connections + networking" (ID: Lola1, Science Educators)*

*"Amazing connection w/ in the field of classroom teachers. I hope we stay in touch!" (ID: Lola1, Other Participants)*

### **Pedagogical Ideas**

*"seeing how they presented and interacted with us gives me ideas for how to interact with my class" (ID: Lucky, Keynote)*

*"Good communications of relatively complicated science. Rethinking how to explain complex astronomical sources of light." (ID:01774, Field Trip Scientists)*

If no social interaction: *"I would have missed out on combating misconceptions and in rethinking content organization, missed out on seeing equipment + experimentation occurring right now" (ID: 01774)*

### **Better Learning/ different perspectives**

*"(if they were not) The learning would have not been as effective" (ID: 33027, Field Trip Scientists)*

*"Learning from people working in the field gave me a different perspective" (ID: 57910, Field Trip Scientists)*

*"Answered all my questions immediately in a way I could understand." (ID: 82666, Science Educators)*

If no social interaction: *"I would not have had their viewpoints, their personal interaction w/ students, access to their knowledge base" (ID: 82666)*

If no social interaction: *"Not learned as much due to keeping questions to myself, not connected as much with the content, not be as inspired as I'm feeling right now!" (ID: Lucky)*

### **Sharing & Collaboration**

*"I grabbed some emails to share lesson ideas :)" (ID: 11123, Other Participants)*

*"Good insights provided. People are all willing to share." (ID: 13021, Other Participants)*

*"I am bringing many of these ideas I saw today to my classroom." (ID: 71901, Other Participants)*

*"It is always great to build ideas with other teachers!" (ID: 88227, Other Participants)*

*"being able to share ideas and brainstorm/problem solve is really helpful, especially as the sole science discipline teacher in my building" (ID: Lpage, Other Participants)*

*"Provided a positive environment to promote open and candid conversations." (ID: 33027, SSEC Staff)*

### **Spontaneous Help**

*"So many interactions! I will miss having their support when I work with these materials" (ID: 71901, Science Educators)*

*"Spontaneous help, I just looked confused and they were there :)" (ID: 82666, Other Participants)*

*"Helpful w/ technology issues + adding perspective" (ID: 01774, SSEC Staff)*

*"They (SSEC Staff) helped me to get through the tech part (Thanks so much!!)" (ID: 11191, SSEC Staff)*

*"I understand a lot better with many staff available to answer questions." (ID: Lucky, SSEC Staff)*

### **Implementation**

If no social interaction: *"I honestly would be intimidated by WWT and the micro-observatory- and therefore would prob not use them" (ID: L2578)*

### **Successful in general**

If no social interaction: *"Being PRESENT is essential. This would not be as successful as it was." (ID: 02472)*



If no social interaction: *"The outcome may not have been a positive or pleasant one"* (ID: 33027)

If no social interaction: *"It is hard to say because I have learned so much. I learned about emphasizing misconception, especially."* (ID: 44750)

## E. Follow-Up Implementation Survey

The Follow-up survey was conducted via online on May-July, 2020, after almost a school year of the Space Science SSEAT 2019. Among 15 participants, 10 responded to the follow-up survey. The survey mainly asked about their implementation of the Space SSEAT contents into their class.

The participants mostly taught secondary science in the school year of 2019-2020.

Teaching Grade	# of participants	Details
Middle School (6-8)	7	6 <sup>th</sup> (Science, 3; Earth Science, 1): 4 7 <sup>th</sup> : 1 7 <sup>th</sup> (Astronomy, Chemistry, Ecology): 1 6-8 <sup>th</sup> Science (earth, life, physical, environmental, health): 1
High School (9-12)	3	12 <sup>th</sup> : 1 11-12 <sup>th</sup> Math: 1 9-12 <sup>th</sup> Science (12 <sup>th</sup> CP Astronomy, 10/11 <sup>th</sup> CP Chemistry, 9 <sup>th</sup> CP Physical Science): 1

Nine out of ten participants implemented the contents that they had learned at the Space Science SSEAT PD into their class, and they revised the resources to fit into their lessons. The one participant who did not implement responded that it was a difficult year, assuming that the pandemic may have affected her/his lessons.

- Q. Reflecting on your teaching during 2019-2020 school year, which of the below best describes you after attending the Space Science SSEAT?

Response Choice	# of Responses
I fully implemented information/resources in my class that I received from the academy to the best of my ability.	0
I revised information/resources that I received from the academy before implementing it in my class.	9
I introduced or mentioned, but did not implement, information/resources in my class that I received from the academy.	0
I did not implement nor mention any of the information/resources in my class that I received from the academy.	1 ("It was a difficult year")

They mostly (5 out of 9) spent several hours on implementing the contents from the Space Science SSEAT into their lessons, which probably on the topics that they were covering in their curriculum. There were two teachers who spent several weeks and one teacher who spent multiple months on implementing the Space Science SSEAT contents in the 2019-2020 school year.

- Q. Reflecting on your teaching during 2019-2020 school year, how much class time in overall do you think you spent introducing or implementing information/resources that you received from the Space Science SSEAT?

Response Choice	# of Responses
One time and less than 30 minutes	0
More than one time but less than an hour in total	1
Several hours	5
Several weeks	2
Multiple months	1
Whole school year	0
No response	1

They implemented various contents that they had learned at the Space Science SSEAT as below. Depending on their teaching grade level and the MA curriculum, the number of implementations varies, but the contents of the Space Science SSEAT were well met to their needs.

- Q. Which of the following did you use in your class? Choose all that apply.

Response Choice	# of Responses
World Wide Telescope (WWT) Think Space: day/night or seasonal change	5
World Wide Telescope (WWT) Think Space: lunar phases or eclipses	1
MicroObservatory: Took astronomical pictures using a remote robotic telescope and processed the images	3
Sun-Earth-Moon model activity using the SEM board	6
Light & Color activity: learned about the characteristics of light by using light & colored cellophane filters	4
Something that you learned from the invited speakers (distinguished scholars)	8
Something that you learned from the field trips to the professional science research center/lab (e.g. Chandra X-ray Telescope Operation Center, CfA research labs)	5

Something that you learned from the field trip to the Harvard Old Observatory (e.g. historic women scientists at Harvard, Old telescope, etc.)	4
Science inquiry and phenomena: Pedagogical tips of using visual images for phenomena	8

Below are the participants' responses to the open-ended questions, asking to describe their implementation experience.

- Q. Please describe your experience of implementing those information/resources or your learning from the Space Science SSEAT into your class. How did you implement and in what context? How did it go? (Please describe as many cases that you did if there were multiple things.)
- *Using Microobservatory to take / edit pictures. Overall, it went well as expected with many students being engaged.*
  - *The MicroObservatory is what was used the most. It was used for filters, lunar phases, exoplanets.*
  - *I teach students Moon phases and Earth's seasons. We use a pre-established curriculum at my school (FOSS) and we have created our own enhancements over the years. I work with two other teachers for the same content so I can't change pacing. I was able to implement several lessons using the video and simulations in World Wide Telescope to help my students practice with Moon phases and Earth's seasons. I also used the domes this year to do the lessons on the Sun's path in the sky. The Space Science SSEAT also gave me a stronger background in the history of women in astronomy and general knowledge about telescopes and telescope imaging. I feel like I can use that knowledge throughout my astronomy unit.*
  - *I am planning on using the sun-earth-moon model in the next few weeks of remote learning. I will demonstrate use of the model in a recorded class demo. I have also had discussions earlier in the year with my students about my trips to the old observatory and Chandra center.*
  - *We used many of the activities on YouthAstroNet and modified Portrait of the Universe to include a presentation which served as our midterm assessment. We used the cellophane filters to introduce the idea of filtering, and combined with activities from Chandra to explore the electromagnetic spectrum. It wasn't part of Space Science SSEAT but we also used the MicroObservatory resource on exoplanets. We used the domes to teach about seasons.*
  - *I purchased and prepared solar/lunar motion kits and the clear dome planetariums right after the session to use this spring. Due to the shift to distance learning just as that unit commenced, I had to transfer quite a few activities into a digital format, so I pulled bits and pieces and added in resources from other places. I was able to use several of the ThinkSpace videos and worksheets (moving worksheet bits into a jamboard for distance editing), and replaced the hands-on bits with some interactive simulators. I did share some other resources outside of class with students in the astronomy event for Science Olympiad, and had plans for a more robust women in science / poetry unit (cut for time this spring). I had also planned a series of mini-units on 'wavelength mysteries' (using different types of information/tools to discover or tell stories) where I hoped to incorporate the telescope/image editing piece that likewise got cut for time. (If I'd known in the fall what was coming...)*
  - *"Light and color was helpful because I also teach Waves: Light and Sound. I end that unit then go into Space. Students like the application of the light waves helps*



*understand about outer space. We spend a two weeks on the season - very hard concept angle of light vs distance from the sun. The model was helpful to work in small groups for students to manipulate and own the knowledge. It was also helpful for phases of the moon and eclipse lessons."*

- *I used the sun earth moon board for eclipses and seasons during remote learning . Great visual for this representation.*

➤ Q. How did your students like/dislike about your lesson? What were students' responses /reactions to your lesson?

- *They liked the artistic qualities of the program and thinking about the objects in space - the limitations include a need for built in time / lessons for training on the program*
- *Most liked the activities. They did get frustrated with some of the activities that required processing many images (ie putting together many moon images to show the phases). They were also frustrated when their images were not received, (School email blocks them) or when it was cloudy and they had to request them again.*
- *They liked the WWT simulation lessons where they worked at their own pace and practiced with the different diagrams and points of view. They also were engaged with the domes and liked my lessons on solar angle.*
- *They were very interested to learn that the Chandra Operation Center was so close to them. We were planning to take a robotics group there for a field trip, but this was postponed due to school closure.*
- *We had some technical trouble with JS9- saving progress in FITS and saving the images caused a lot of confusion for students and required a lot of one-on-one support. I think the color filters and activities from Chandra combined really well because they seemed to understand EMR a lot better after our unit.*
- *Hard to gauge in distance learning mode. The pages from the thinkspace curriculum I modified were really helpful, and the videos about perspective helped solidify the idea of thinking about space from different directions.*
- *6th graders love space! We spend two weeks on the moon. Many stated after they were seeing the moon more often.*
- *The board demo generated many questions*

➤ Q. What were your challenges, if any? And, how did you resolve them?

- *The challenge was that students never received emails with their pictures that they had asked the microobservatory telescopes to take. I'm not sure if that's an issue with the gmail school domain or other challenge, but that prevented us from closing the circle on the lesson of using this tool*
- *Since we don't see students everyday getting them to remember to request images over multiple days when they did not have an in class reminder was tough.*
- *I think the WWT lessons on Moon phases need to be fleshed out a little more. I did the simulation lesson too early I feel like in my lessons and it would have worked better as a formative assessment after more structure teacher led practice with the diagram. I would do that in the future.*
- *No challenges yet, I anticipate the modeling lesson will go well.*
- *Next time I will adapt the WWT materials to target my older students. I might also try setting up folders for the students to save their work from JS9.*
- *Time, distance, lack of physical ability to DO things...because this content overlapped with the beginning of distance learning due to the lockdown, it was greatly abbreviated for time and constrained by lack of hands-on pieces. Replacing hands-on with some excellent simulators (<https://astro.unl.edu/naap/>) and moving some parts from 'pencil/paper' to digital formats helped. I'm really looking forward to a 're-do' next year with all the parts in place!*



- *Differentiating lessons for students.*
- *I showed a video to accompany the demo*

Below are the participants' responses to the open-ended questions about their thoughts of learning experience, their teaching and students learning influenced by attending the SSEAT, and any adjustment due to COVID.

- Q. What was the most interesting learning experience that you remember from the Space Science SSEAT?
  - *Each lecture and our visit to the X-ray observatory*
  - *Touring the Chandra control facility*
  - *How to get pictures*
  - *the scientist who spoke about their childhood experiences that excited them to learn more*
  - *Seeing the Chandra Operating Control Center, the Harvard telescope, and the collection of plates were all very memorable experiences. I liked talking to the scientists and seeing their labs too. It's hard to pick just one and I could definitely name several other memorable experiences.*
  - *I really enjoyed visiting the cfa research labs. I worked in research in my first years out of college, and I really enjoyed seeing working labs. It definitely gave me an appreciation for the various ways that space science overlaps with other disciplines.*
  - *Seeing the glass plates and learning about the history of Astronomy was extremely interesting. I realized that a lot of people including myself and my students expected astronomy to be about being outside at night and looking through a telescope, but it makes sense that the data would be collected visually (and now digitally) for a more thorough analysis.*
  - *I LOVED the wonder of being in the Chandra observatory and the Old Observatory. That was the most personally inspiring piece.*
  - *the scientists!*
  - *The sun moon earth boards!*
- Q. Please describe if there is anything from the Space Science SSEAT that influenced you as a teacher or your teaching.
  - *utilizing certain visual resources / demos*
  - *I used the MicroObservatory so much I don't think I could teach without it.*
  - *Th wonder of the Universe*
  - *different hands-on activities for lessons*
  - *I feel like I could confidently teach a high school astronomy course now because of the Space Science SSEAT. It was great how expansive the week was in terms of content.*
  - *I appreciated the time we spent working with models and with other teachers. We don't often get the opportunity to work with teachers outside our districts.*
  - *I was really influenced by the use of MicroObservatory. I think it's amazing for anyone to be able to access the telescopes, and the possibilities are endless!*
  - *I definitely took away new ideas for eliciting misconceptions in science (and shared some pieces of that in a fall PD with colleagues and one for parents). I now have a good 'basket' of tools to use to help explore lunar/solar/season concepts, with a variety of different approaches based on the needs of my students and curricular connections.*
  - *All of the hands-on lesson ideas.*
  - *The group dynamics were great!*



- Q. How do you think your learning at the Space Science SSEAT may have affected your students?
- *In a small but positive way*
  - *I think that the class was able to be much more project based because of what I learned at the Space Science SEAT*
  - *Maybe they will think about the universe more.*
  - *since I was more excited, they were more excited*
  - *I brought more hands on inquiry and more opportunities for independent practice into the classroom.*
  - *I hope that I was able to give my students ideas about how they could extend their love of science and experimentation into a future career.*
  - *My students definitely got a more up-to-date hands-on and inquiry-based experience because prior to Space Science SSEAT I was planning to do more lecture-based lessons, which is the way I learned about astronomy in school.*
  - *Hopefully, through renewed enthusiasm, through more soliciting of understanding in new formats (even across other topics), in thinking about how to make other subjects inquiry based that I hadn't moved to that format prior.*
  - *I was more excited to reach t - they were more excite to learn.*
  - *"I'm more confident in my knowledge of these areas of space science "*
- Q. Based on the current situation due to COVID-19, how did you need to change/cancel your original plan to implement resources from the Space Science SSEAT, if at all? Or, are there any Space Science SSEAT resources that you plan to use (or are using) for distance learning? If so, what and how?
- *None*
  - *I will not be using any resources from the Space Science SSEAT for the remainder of the year.*
  - *Our goal is to just get any learning.*
  - *no, already taught this unit*
  - *I was done with astronomy in November- so there wasn't any change due to COVID-19.*
  - *I usually teach my space science unit at the end of the year, so my plans have been completely changed. I am adapting resources to teach as a recorded demo rather than in class activities.*
  - *We had progressed into a unit on space exploration and cosmology. This isn't from Space Science SSEAT but the Concord Consortium has a High Adventure Science sequence on Life in Space which my students have been working with during remote learning.*
  - *I had already taught that unit.*
- Q. Do you have any additional stories that you want to share with us (e.g. your teaching or learning from the Space Science SSEAT academy, any further interaction with any of the SSEAT presenters after the academy, or arranging a field trip to any of the places you visited during the SSEAT, etc.)? Or, any other comments?
- *No*
  - *I would love to take another class- it was such a useful and inspiring week!*
  - *I appreciate how much work went into the SSEAT academy and it really payed off. Thank you. I feel like I learned so much and I'm glad I got the opportunity to attend.*
  - *We were able to help Mary and Pat with the preliminary development of materials for Spectroscopy.*
  - *"The Space SSEAT for me was immediately followed by a week at the Walden Woods Project, where we thought a lot about what it mean to 'see' and know. Lots of surprising resonances between the two workshops! One synthesis that came out of the two was*



*incorporating some biographies of 'often overlooked' scientists, particularly women and poc, in various places through this year. Vera Rubin, who we heard a lot about, made the list. :-) I loved the whole week, and hope to bring more pieces of what we learned, including visits to the Observatory, into my teaching over the next few years. Thank you!"*

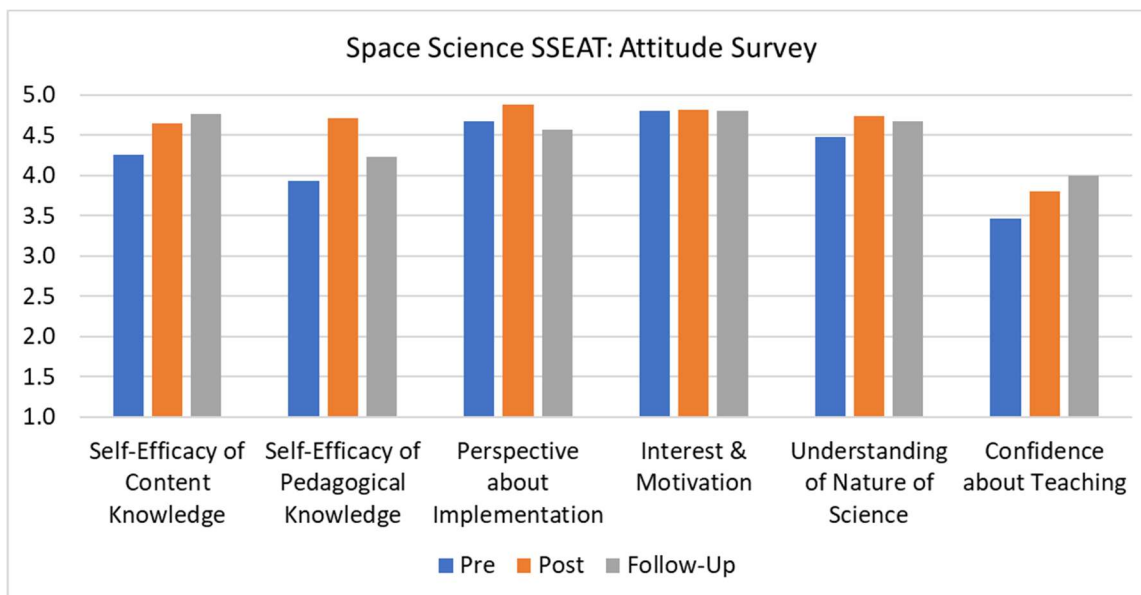
- *It was a nice group of teachers to work with, many great ideas shared.*

Finally, the same attitude survey questions were asked, consisting of 6 constructs of self-efficacy and interest. The results are summarized in Table below with the former results. The survey questions are in 5 Likert-scale (1: Strongly Disagree – 5: Strongly Agree).

Attitude Survey (Pre/Post: n=14, Follow-up: n=10)			Pre (Before PD)	Post (Right after PD)	Follow- Up (after 1 year)
A. Self-Efficacy of Content Knowledge	<ul style="list-style-type: none"> <li>• I have a good understanding of the concept of seasonal change.</li> <li>• I have a good understanding of the concept of lunar phases and eclipses.</li> <li>• I am knowledgeable on space science concepts that I teach.</li> </ul>	Mean	4.26	4.65	4.77
		Std. Error Mean	0.14	0.09	0.13
B. Self-Efficacy of Pedagogical Knowledge	<ul style="list-style-type: none"> <li>• I am knowledgeable on student misconceptions in space science.</li> <li>• I have pedagogical ideas to teach science as inquiry.</li> <li>• I am knowledgeable of using various forms of representation in my instruction (visual images, models, etc.).</li> </ul>	Mean	3.94	4.71	4.23
		Std. Error Mean	0.12	0.08	0.21
C. Perspective about Implementation	<ul style="list-style-type: none"> <li>• I can integrate technology in my instruction.</li> <li>• Integrating technology can enhance students learning and interest in science.</li> <li>• I am comfortable with implementing hands-on materials/resources in my instruction.</li> </ul>	Mean	4.67	4.88	4.57
		Std. Error Mean	0.09	0.07	0.26
D. Interest & Motivation	<ul style="list-style-type: none"> <li>• I am interested in learning about astronomy and space science.</li> <li>• It is interesting to learn about cutting-edge science research findings.</li> <li>• Meeting scientists in the field motivates me to teach science.</li> <li>• Learning about science history enhances my interest in science.</li> </ul>	Mean	4.80	4.82	4.80
		Std. Error Mean	0.09	0.10	0.07

E. Understanding of Nature of Science	<ul style="list-style-type: none"> <li>• Understanding about how scientists proceed science research helps me teach science in class.</li> <li>• Scientific method is an iterative process.</li> <li>• Science theories should not be changed over time. (N)</li> <li>• Science research should be independent, not interdisciplinary. (N)</li> </ul>	Mean	4.48	4.74	4.68
		Std. Error Mean	0.15	0.08	0.12
F. Confidence about Teaching	<ul style="list-style-type: none"> <li>• I am confident to teach science.</li> <li>• I am comfortable teaching space science in my class.</li> <li>• There are space science concepts that I get confused when I teach. (N)</li> </ul>	Mean	3.46	3.81	4.00
		Std. Error Mean	0.17	0.22	0.15

Note: Those negatively asked questions (with the sign N in the table) were converted into the adjusted scales in calculation.



While it is difficult to compare directly between the last year's data and this year's data (e.g. matched-samples t-test is not applicable), the results show that the participants' learning is affected even after a year of attending the Space Science SSEAT. Especially the self-efficacy of content knowledge is even higher than at the post-survey, meaning that the participants' learned about the space science concepts at the PD and it increased their confidence on the content knowledge. Self-efficacy of the pedagogical knowledge and perspective about implementation are a bit lower in this follow-up survey, which is expected that the pandemic may have affected them to struggle by adjusting their in-person class into virtual class among

other factors (that are beyond the scope of the study). Their interest and motivation stay high and they show a good understanding of the nature of science. One interesting finding is that their confidence of teaching, along with the self-efficacy of content knowledge, is increased, higher than at the post-survey.

## **F. Discussion**

### ***Learning Experience by PD modes***

Many science museums and informal learning institutions provide PD for teachers (Phillips, Finkelstein, & Wever-Frerichs, 2007). Different from workshops that are provided in formal settings (e.g. school classroom), science museums or institutions have unique facilities that teachers can interact with and depending on their capacities the PD program can provide teachers with diverse learning experiences. In the Space Science SSEAT academy, we provided the participants with six different modes of PD sessions, and we investigated how the participants perceived their learning and what they valued at each mode. The modes included: hands-on classroom activities (no technology), hands-on classroom activities (with technology integration), analysis of authentic science data using technology, science lectures by distinguished scholars, field trips, and science inquiry and planning.

The hands-on classroom activity mode (with no technology integration) may be the most common type of PD that are provided at informal settings. The participants found benefits in this mode by providing pedagogical ideas, interactive work with others, learning from sharing and collaboration, getting to understand science concepts and students' ideas better, and materials that they can easily implement in their classroom. The hands-on classroom activity with technology integration mode is similar to results we saw in the hands-on activity without technology integration mode. The Figures 4 through 10 show that the teachers' responses were more positive with technology integrated hands-on activity than without. The responses could be different depending on several factors, such as the difficulty of the covered concepts, duration of the sessions, or the participants' interest about technology, etc., but usually it takes time for participants to get familiar with technology and studies have reported that there is a resistance among many teachers to learn to use technology. However, the results show that depending on how the PD is designed, the participants could have more positive learning experience with technology integration. For example, the WWT session (the hands-on classroom activity with technology integration mode) was provided with already well-developed lesson

plans and teacher guidance with student worksheets, and the level of the technology integration was adjusted to be appropriate for the week-long PD. In addition, the presenter was very explicit with where and how to integrate the technology in the hands-on activity. In that, the participants may have developed clear ideas of how to use it in their own class.

In the mode of analyzing authentic science data using technology, the participants valued the real-world experience of working with the real science data. Some of them experienced difficulties in the beginning but they became more comfortable later the week. However, fewer participants found it easier to implement in class than the second mode, hands-on activity with technology integration (Figure 7), both of which introduced new technology during the week. The topic of the second mode was closely related to the concepts of the K-12 science standards and its associated lesson plans, while the topics of the third mode were more advanced that were not covered much in the K-12 science standards.

In the fourth mode, science lecture by distinguished scholars, the participants appreciated hearing the scholars' professional knowledge and their stories, and the participants valued the scholars' enthusiasm and insights of science, which inspired them a lot. Similarly, the participants found value in the field trips, the fifth mode, as they were inspired by the professional scientists and seeing their workplaces. They could also recognize that science is interdisciplinary. In addition, the field trips were appreciated because it allowed teachers to learn something new (Figure 5) as well as deepen their understanding of science concepts (Figure 4), it increased their interest in science (Figure 8), and they were able to better understand how scientists do their research (Figure 9). Finally, the last mode, the science inquiry and planning mode was most appreciated that they were able to get pedagogical content ideas (Figure 6) that they could bring to their class (Figure 7). And they believed their confidence in teaching the content was increased (Figure 10). In addition, they valued reflecting their learning of the week and sharing ideas with other participants.

The most important take-aways reported from the week was getting all the pedagogical ideas, such as investigation of student misconceptions; ideas for student assessment; how to use models and resources; how to manage and facilitate students' thinking; and using visual representations into scientific inquiry. They also liked to know places that they could bring their students to and how to get research ideas that they could do with their students in class. They also liked to bring what they saw and whom they met during the week to their students, which resulted them to better understand scientific process and nature of science.

Based on the findings, below table summarizes some suggested strategies for each type of PD mode with its expected learning.

PD mode	Expected Learning	Strategies
Hands-on classroom activity (no technology integration)	<ul style="list-style-type: none"> <li>• Better understanding of the concepts (CK)</li> <li>• Getting pedagogical ideas to integrate (PCK)</li> <li>• Learning to use models and new hands-on resources</li> </ul>	<ul style="list-style-type: none"> <li>• Provide ready-to-use lesson plans that can go with the activity and that are aligned to the science standards</li> <li>• Provide the hands-on materials that teachers can bring to their classroom</li> <li>• Integrate pedagogical ideas during the session</li> <li>• Investigate student's misconceptions</li> </ul>
Hands-on classroom activity with integrating technology	<ul style="list-style-type: none"> <li>• Better understanding of the concepts (CK)</li> <li>• Getting pedagogical ideas to integrate (PCK)</li> <li>• Becoming comfortable with integrating technology into instruction</li> </ul>	<ul style="list-style-type: none"> <li>• Provide ready-to-use lesson plans that can go with the activity and that are aligned to the science standards</li> <li>• Provide the hands-on materials that teachers can bring to their classroom</li> <li>• Integrate pedagogical ideas during the session</li> <li>• Investigate student's misconceptions</li> <li>• Provide step-by-step guidance of using the technology</li> <li>• The technology should be easily accessible in their schools</li> <li>• Be specific and clear when and how to use the technology</li> </ul>
Science Data analysis using technology	<ul style="list-style-type: none"> <li>• Unique experience to work with real world data that scientists use</li> <li>• Getting ideas and resources for student research</li> <li>• Better understanding of scientific method and the nature of science</li> </ul>	<ul style="list-style-type: none"> <li>• Provide goals, big picture, and the background of how the data came from and how scientists used them to investigate what</li> <li>• Provide step-by-step guidance of using the technology</li> <li>• The technology should be easily accessible in their schools</li> <li>• Provide related concepts (DCI or CCC) that teachers can easily integrate for</li> <li>• Provide possible contexts that can be easily revised and adapted (e.g. after school program, gifted program, senior research program, etc.)</li> <li>• Provide networking, webpages, or discussion boards with professional scientists, educators, or other groups of teachers that the teachers can continue to communicate</li> </ul>

Science lectures by distinguished scholars	<ul style="list-style-type: none"> <li>• Unique experience to meet and hear the scholar's research</li> <li>• Getting inspired and motivated about science &amp; scientists' work</li> <li>• Learning cutting-edge topics and science concepts</li> <li>• Learning about Nature of Science (including, "Science is a Human Endeavor" NGSS' NOS matrix)</li> </ul>	<ul style="list-style-type: none"> <li>• Provide a big picture of the meaning of the science research</li> <li>• Explain how the science work is connected to the science concepts that the teachers teach in school, or provide the examples of how the science work is related to our lives</li> <li>• Use visual images that can help teachers better understand</li> <li>• Use common languages and avoid scientific jargons</li> <li>• Stories about how they became scientists can inform teachers who can guide students into science careers</li> </ul>
Field Trips	<ul style="list-style-type: none"> <li>• Unique experience to visit cutting-edge science research centers and/or historic buildings and to see the real-world experiment &amp; research in action</li> <li>• Meeting scientists and learning about their work in their space</li> <li>• Learning of scientists' enthusiasm</li> <li>• Getting inspired by the scientists, their research &amp; work, and the scientific artifacts (e.g. instruments, archives, buildings, lab atmosphere)</li> <li>• Increased interest and motivated about science</li> <li>• Opportunity to broaden the view of science and to learn something new</li> <li>• Better understanding of scientists and the nature of science</li> </ul>	<ul style="list-style-type: none"> <li>• Provide some background information about the field trip place before the visit (e.g. What is the place for? What do scientists work there? Any differences or similarities between places in terms of their research, finding, related science, what topics to bring from? etc.)</li> <li>• Inform the participants if there are anything that need to be cautious (e.g. do not take pictures, do not touch, your shoes need to be free from dust before entering labs, any safety issues or security issues, etc.)</li> <li>• Provide a big picture of the meaning of the work that is conducted at the place</li> <li>• Use common languages and avoid scientific jargons</li> <li>• Show how scientists do their work, by lots of trials and errors, modifications, lots of failures, lots of collaborations, interdisciplinary, etc.</li> <li>• Explain how the science work is connected to the science concepts that the teachers teach in school, or provide the examples of how the science work is related to our lives</li> <li>• Stories about how they became scientists can inform teachers who can guide students into science careers</li> </ul>
Science	<ul style="list-style-type: none"> <li>• Getting pedagogical</li> </ul>	<ul style="list-style-type: none"> <li>• Provide enough time and support for teachers</li> </ul>

Inquiry and Planning	ideas to integrate (PCK) <ul style="list-style-type: none"> <li>• Having reflection and planning time to digest and to apply into their instruction</li> <li>• Learning from others by sharing and collaborating</li> <li>• Networking between teachers who can continue to communicate</li> <li>• Increasing teaching confidence</li> </ul>	to digest what they have learned <ul style="list-style-type: none"> <li>• Provide time that teachers of teaching similar grade levels work together as small groups</li> <li>• Let teachers share their planning and get feedbacks from others</li> </ul>
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### ***Physical and Social Contexts of PD in Learning***

Professional development that takes place at an informal setting can provide a richer experience to participants due to its physical context and social context. Meeting with scientists and scholars inspires participants, and it increases their interest and motivation about science. And it helps them better understand who scientists are, what and how they work, and learn about all their efforts, trials and errors, failures and success, curiosity, patience, and attitude about science. It also decreases the gap between scientists and participants, and it gives an opportunity for participants to network with professional scientists, which provides chances that teachers can organize special events for their students to meet with the scientists. By sharing and collaborating with other participants during the PD, they reflect on what they have learned and what they will bring to their classroom. They discuss and develop their lesson plans and students' learning together.

Physically visiting to the cutting-edge science center and research labs inspires participants and increases their interest and motivation in science. Participants feel more connected to science and the rich and first-hand experience provides them with unforgettable memories that they can bring to their students. It broadens their view about how to look at science and to better understand the nature of science. It is a valuable experience that they meet current or past scientists in their current labs or historic buildings, as can be seen in the quotes,

*Magical- the old observatory was like going back in time.* (ID: L2578, CfA Old Observatory)

*Felt like I was walking in the shoes of the past "greats" - stepping into Hogwarts. Magical!* (ID: Lpage, CfA Old Observatory)

*Beautiful new facility. I don't think I would ever have an opportunity to go to a place like that...it's like from a movie!* (ID: 88337, Chandra)

However, the degree of individual's learning can differ depending on their background, experience, interest, their content knowledge or pedagogical knowledge, etc. (Personal Context). Someone may increase their interest more than gaining knowledge, or someone may appreciate more working with other participants to develop their instruction rather than visiting science research labs.

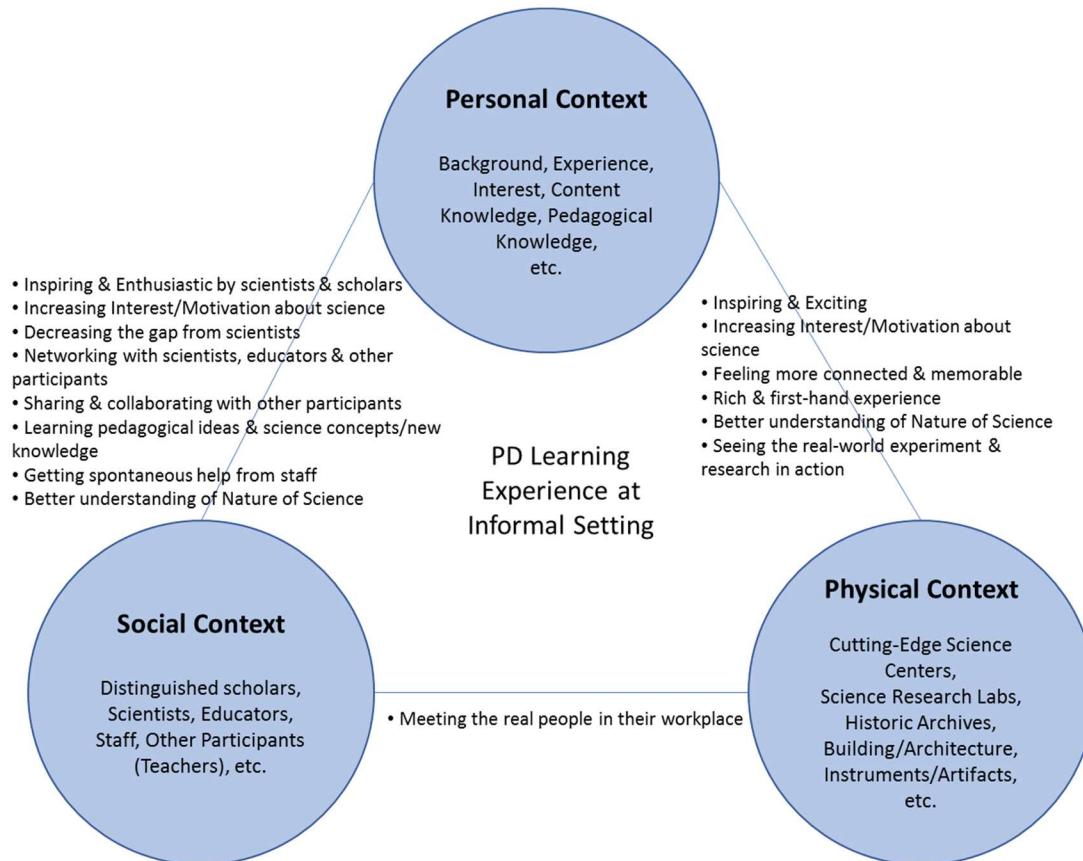


Figure 410. PD Learning Experience of Informal Setting Model

This model describes how learning happens when PD takes place at informal setting. The Smithsonian Institution has provided many quality PD programs to teachers with the benefits of valuable resources that the museum facilities and collaborating research centers have. I believe this model provides the background theoretical framework of such PDs and this will be useful for PD developers in designing even more quality PDs in the future in Smithsonian.

#### Reference:

Phillips, M., Finkelstein, D., & Wever-Frerichs, S. (2007). School site to museum floor: How informal science institutions work with schools. *International Journal of Science Education*, 29(12), 1489-1507.