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Summative Evaluation of NOVA Labs: Cloud Lab

Report of Findings

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Executive Summary

NOVA Labs (www.pbs.org/nova/labs) is a web-based platform designed for use by educators, students, and teens to engage learners with authentic data, processes, and tools of working scientists. The present evaluation study sought to investigate the outcomes achieved by users of the third NOVA Labs platform developed: Cloud Lab.

The intended outcomes identified for student users were that they would:

- Be able to successfully work with the real data provided in the Cloud Lab;
- Demonstrate ability to interpret and use scientific data and tools;
- Engage with real scientific data through the Cloud Lab

The intended outcomes identified for teacher users were that they would:

- Be able to successfully facilitate lessons using the NOVA Labs resources;
- Explore new and innovative ways to deploy NOVA Labs for teaching science content;
- Demonstrate interest in further opportunities to incorporate real scientific data in the classroom.

The evaluation used multiple methods. The primary approach was identifying five teachers across the country who intended to implement Cloud Lab in Fall 2013. From these test classrooms (grades 5-8), evaluators collected pre/post-test data from their 300+ student users, and post-implementation interviews with the teacher-users. Supporting this study, was an effort to survey teachers known to NOVA Education as possible Labs users. A web-based survey was sent to 138 teachers identified by NOVA Education; 37 responded, 21 of whom were Cloud Lab users.

Key Findings

Overall, the Cloud Lab was successful at achieving its goals with the teachers who used it in the Fall 2013 semester.

- **Students were successful working with the real data provided in the Cloud Lab.** Students reported generally feeling successful with the Lab activities, although feeling a degree of challenge in doing them. Teachers reported that the majority of their students were able to be successful with the activities; although this was more true of the Cloud Typing than Reconstruct A Storm. Teachers also believed that the Cloud Lab content was "about right" for the students at their grade level.
- **Data indicated that use of Cloud Lab increased student knowledge of key meteorology concepts and ability to read, analyze and interpret data visualizations related to the Lab's content.** Students appeared to demonstrate the greatest growth in their ability to interpret and use scientific data.
- **Students were engaged and interested in the Cloud Lab and its use of real data,** with most reporting they liked it better than "usual school work." Students were aware they were using real data in Cloud Lab and reported they liked using real data in school. Surveyed teachers strongly felt students responded well to the fact that Cloud Lab addressed a relevant/real issue, had an activity-based structure, and used a game like design. These results echoed earlier evaluations of other NOVA Labs.

- **Teachers in this sample were able to successfully incorporate the Cloud Lab into their lessons**. As with prior evaluation of Sun Lab and Energy Lab, teachers report the videos in the Labs are an incredible strength. Lab activities are also strong, but are generally the areas where there are more critiques and suggestions for further development. A theme that was seen in these data, and echoes earlier findings of the Energy Lab, was that increased scaffolding for student engagement with the Lab is needed.
- **Pre-existing enthusiasm for and experience with data in the classroom may be a common attribute of many teachers who come to NOVA Labs**. However, even with prior experience, these test-group teachers were impressed with Cloud Lab and plan to continue using it with their students. **The majority of surveyed teachers indicated they experienced "some change" to their overall approach to teaching, use of technology, and incorporation of data from scientists.** They rated the quality of Cloud Lab videos, Cloud Typing, and Reconstruct a Storm highly and plan to continue using Cloud Lab with their students.

Recommendations & Future Considerations

Based upon the findings and feedback resulting from this study, a few recommendations emerged for consideration by the NOVA Labs team as they develop future NOVA Lab environments. These recommendations are informed by the data from the Cloud Lab study, specific recommendations that were heard; recommendations bring an emphasis on those themes that were reminiscent of findings and recommendations from studies of earlier Lab content areas.

- Consider adding additional information to the Educator Guide to ensure teachers know how to best scaffold any NOVA Lab for their student's abilities and knowledge. As the program may reach out to a broader range of teachers (perhaps with less experience using tools like this), greater amounts of support and ideas for implementation may support a broad reach.
- In the Cloud Typing challenge, consider identifying the cloud height in images to support students in identifying images. In future Labs, looking for elements of challenges that might be difficult to interpret without additional context may be advised.
- In support of challenges that use an identification-type key as part of the work, consider modifying the Cloud Identification key (or creating new keys) to be a dichotomous key format; some teachers reported this being a more familiar format for students.
- In challenges, such as the Reconstruct A Storm challenge, consider including more and varied types of storms or structured activities for students. The greater number of individual examples or activities within a type of Challenge would be valuable to teachers and students. Often, a Labs challenge requires practice and advancing through levels of difficulty for students to reach a better level of understanding the concepts. Having more structured options to do would be a benefit for teachers and learners.
- Continue focusing on creating activities and challenges around an "average student-user." Teachers continue to report the need for more scaffolding of activities to increase student understanding. The Labs are strong overall, but this is the area that seems to allow for greatest improvement.
- Consider the limitations to understanding NOVA Labs that relates to the ability to identify and sample actual users. In this study, 42 teachers were identified to participate; 27 had used Labs. Consider strategies to identify who the users are of the Labs platform to aid in better measurement. Similarly, a larger study of the educator population may help further aid understanding of the audience.

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Background

NOVA Labs (www.pbs.org/nova/labs) is a web-based platform designed for use by educators, students, and teens to engage learners with authentic data, processes, and tools of working scientists. The NOVA Labs platform includes:

- Multiple individual, topic-specific labs (Sun, Energy, Clouds, etc.)
- Contextual sections/information—opportunities to interact with scientists, opportunities for teens, educator guides, and an online social network.

There are two kinds of Labs within the platform; science labs give access to data and analysis tools for scientific research, while engineering design labs enable the design and testing of systems and models.

Each individual Lab component includes standard components:

- Three Video Modules, each containing 2 or 3 individual video shorts and their accompanying assessment questions. Questions can be multiple choice or open-ended.
- A Research Challenge section that contains one or more guided investigations.
- An Open Investigation section that connects users with data stream(s) and analysis tool(s). In this area, research projects can be designed or live data can be explored. This feature only applicable to the science labs, not the engineering design labs.

This online educational resource has been created to serve middle and high school students and teachers by providing rich classroom resources to 1) increase the use of real data and scientific processes by teachers; and 2) engage students in the skills of working with real science data and support their science learning.

The Cloud Lab: Outcomes and Evaluation Questions

The present evaluation study sought to investigate the outcomes achieved by users of the third NOVA Labs platform developed: Cloud Lab. The Cloud Lab was developed for two main target audiences: teens/students and teachers. It was anticipated that the Cloud Lab would be used primarily by teachers in the classroom.

The NOVA Education team's overarching goals for youth using the Cloud Lab in school focused on learning content and increased interest or engagement with authentic data and science. Upon development of the Cloud Lab, educators defined the specific outcomes for youth using NOVA Labs generally, and specifically for the Cloud Lab. They intended that students who used the Cloud Lab in a classroom would:

- Be able to successfully work with the real data provided in the Cloud Lab;
- Demonstrate ability to interpret and use scientific data and tools;
- Engage with real scientific data through the Cloud Lab

The secondary audience was middle and high school teachers who integrate NOVA Labs into their science curricula. This audience emerged as a kind of "gatekeeper" for accessing youth users, and their engagement with the materials became an important second area of impact for the project. The goals for this audience are that the content, format, and components of a Lab align and/or connect with their curricular needs and that teachers are able to successfully integrate NOVA Labs into their instructional plans. Specifically, the intended outcomes were that teachers who used the Cloud Lab would:

- Be able to successfully facilitate lessons using the NOVA Labs resources;
- Explore new and innovative ways to deploy NOVA Labs for teaching science content;
- Demonstrate interest in further opportunities to incorporate real scientific data in the classroom.

With this context, the summative evaluation of the Cloud Lab sought to address the following evaluation questions:

- To what extent are the targeted short-term learning outcomes (outlined above) achieved with teens through the Cloud Lab?
- What attributes of the NOVA Labs experience are most compelling for teens?
- What attributes or features of the Cloud Lab are confusing or difficult to understand?
- How is the use of NOVA Labs providing value to teachers' classroom practice?

Methods

The evaluation used multiple methods to answer these questions. In order to assess outcomes with teens who have used Labs, classrooms that would test the Cloud Lab during the Fall Semester 2013 were identified. A group of five classrooms were recruited from contacts of NOVA Education who intended to use Cloud Lab in 2013. With these recruited classrooms, two methods were used to collect data: 1) pre/post survey of teen-users and 2) telephone interview of teacher-users. A third method was used in an effort to gather data from the broader population of teachers that were thought to have used the Cloud Lab (or other NOVA Labs) in 2013 - a post survey of NOVA Education's teacher email list for Labs was conducted. See Appendix for all instruments.

Pre/Post Survey of Students
A pre/post-test was developed to assess students' prior knowledge and skills that would be covered in the Cloud Lab, as well as to assess change in their knowledge and skills after the Lab experience. Additional questions measuring students' interest and engagement with the Lab were also included in the post-test. Teachers administered the pre-test prior to their introduction of the unit in which they would use NOVA Labs. At the conclusion of the unit, the teachers administered the post-test to students. Four of the five teachers collected data using an online questionnaire, one teacher collected data using paper and pencil.

Follow-up Telephone Interviews with Teachers
The five test-group teachers participated in a semi-structured telephone interview following their implementation. These interviews focused on documenting teacher implementation to contextualize the student outcome data, as well as address questions about the potential influence of NOVA Labs on educators' practice and classroom value.

Post Survey of Teachers
In an effort to gather a broader sample of teacher feedback about the NOVA Labs, an online survey was distributed to an email list of 138 teachers provided by NOVA Education as those who identified that they were inclined to use NOVA Labs in the classroom. Data were collected via online survey, with links emailed directly to potential participants. Teachers were screened for which, if any, of the Labs they had used in the classroom. Data were gathered from teachers who had used any of the Labs, and where appropriate, results are reported separately for the Cloud Lab users.

Description of Samples

Test-Group Classrooms

Table 1 presents the characteristics of the five teachers/classes who participated in the test-group study of Cloud Lab (also referred to as "interviewed teachers" throughout the report). Four of the classrooms were middle school (7th and 8th grade), while one was a 5th grade classroom. Some teachers used the Cloud Lab with multiple sections or classes taught. Three schools were public, and two were private, and schools represented suburban and rural locations in the East, Midwest, and West of the U.S.

Table 2 outlines the technology resources available to these teachers. The technology available impacted how the teachers presented the Cloud Lab to their students. Access to technology resources available to these teachers varied, from one computer in the classroom to a computer for each student in the classroom. The two teachers who used the computer lab shared their frustrations on reserving the computer lab as it required extra planning and precise timing on their part. For example, one teacher taught the Cloud Lab before students watched the videos because of computer lab scheduling.

Table 1. Characteristics of test classrooms in the evaluation

Class	Grade(s)	Number of Students Completing Pre/Post Test	School Type	Location
1	8	107/101	Public	Suburban California
2	7	38/35	Private	Suburban Pennsylvania
3	5	53/47	Private	Suburban Washington
4	7	101/96	Public	Suburban Massachusetts
5	8	23/28	Public	Rural Wisconsin

Table 2. Technology available to test group teachers and students

Class	Technology Available
1	One computer connected to LCD Projector in classroom, Computer lab, Wi-Fi enabled soon
2	All students either have their own laptop/tablet or use one provided by school, Wi-Fi enabled
3	School provides laptop for each child to use in classroom, Wi-Fi enabled
4	One computer, Smartboard in classroom, Computer lab, School to be abandoned at end of year, investment into technology for the new school
5	5 laptops in classroom, Computer lab, Traveling iPad cart, Wi-Fi enabled for 2 years, just getting Smartboards

Teacher Survey Respondents

Thirty-seven teachers responded to the invitation to complete the teacher-survey and answered all or part of the questionnaire; a response rate of 27%. These teachers were separated into groups for analysis, based upon their use of Labs (and the corresponding questions answered in the survey). Twenty-one teachers (57% of respondents) had used Cloud Lab; 15 teachers had not used any NOVA Labs; and one teacher had used Energy and Sun Lab, but not Cloud Lab. For questions that were applicable to all teachers (e.g., awareness of Labs, likelihood of use in the future), results are presented for All Respondents (n=37). For questions specific to the Labs, this report focuses on the results of the Cloud Lab users (n=21) (also referred to as "surveyed teachers" throughout the report), unless otherwise referenced.

Tables 3-8 present the demographic composition of the entire sample. All of the surveyed teachers teach grade 5 and higher, including one post-secondary instructor. The majority could be classified as middle and/or high school teachers. Most of the responding teachers taught earth science (18), general science (16), and/or life sciences (12), and were very experienced teachers with more than half having more than 15 years of teaching experience. Most taught at public schools (22), and about half of the schools were Title 1 schools (14). Seventeen out of 28 report that fewer than 50% of their students receive free or reduced meals.

Table 3. Grades taught by teachers responding to web survey (n=29)

Grade Level	Frequency
Elementary	3
Middle	12
High	9
Middle & High	4
Post-Secondary	1

Table 4. Subjects taught by teachers responding to web survey; multiple selections allowed (n=29)

Subjects	Frequency
Earth Sciences/Astronomy	18
Science-general/integrated	16
Life Sciences/Biology	12
Chemistry	8
Other	6
History	5
Physics	4
Math	4
Computer Sciences/Technology	3

Table 5. Years of experience teaching (n=28)

Percentage of students eligible for free or reduced meals?	Frequency
1-5 years	2
6-10 years	6
11-15 years	4
15+ years	16

Table 6. School type (n=28)

School Type	Frequency
Public	22
Private	6
Homeschool	0
Charter	0

Table 7. Title 1 Schools (n=29)

Title 1 School	Frequency
No	15
Yes	14

Table 8. Percentage of students receiving free or reduced meals (surveyed teachers; n=28)

Percentage Free/Reduced Meals	Frequency
0-25%	9
26-50%	8
51-75%	4
76-100%	7

In response to a question about teachers' experience with or thoughts about the "flipped learning" or "flipped classroom" model, the group of respondents had not widely adopted this model – only 8 of 29 had tried it (seven are using it; one had tried it and found it didn't work). The two most common responses to the idea of "flipped learning" of those who had not yet tried it were interest to try it this year (8 teachers) and concern about technological access for all students at home to be able to do this model (9 teachers). These results were consistent with results from teachers surveyed after the Energy Lab was completed.[1] See Table 9.

Table 9. Teachers' thoughts on "flipped learning" (n=29)

Teacher's thoughts or experiences with the "flipped learning" model	Frequency
I am concerned that my students would not be able to access the videos at home	9
I am interested in trying it this year	8
I am doing this in my classroom with videos that I have found online	6
To do this I would need instruction in how to make the videos	2
I am doing this in my classroom using videos that I am creating of my own lessons or lectures	1
I tried doing this last year but it did not work for me	1
I have heard about this but I am not interested	1
To do this I would need instruction on how to find high quality videos online	0
To do this I would need instruction on how to best utilize the classroom time	0
I have never heard of this before	0

Awareness of NOVA Labs

When asked to share how they learned about NOVA Labs, the majority of surveyed teachers, both Cloud Lab users and All Respondents, learned about NOVA Labs from a link on the NOVA Education website. This is indicative of this small sample, as teachers were recruited through a list provided by NOVA Education staff. A truer understanding of how individuals learn about NOVA Labs would require different methodology and a larger, random sample.

One surveyed teacher shared:

> *"I'd like to see them be publicized more - I'm a big fan, and only just realized what they were. Demonstrate at NSTA, CSTA, CUE or other technology conferences, or advertise them via NOVA Science Now."*

[1] See: Sickler & Wojton (July 2013). Evaluation Report: Energy Lab, prepared for WGBH Education. It should be noted that some of the responding teachers may have been the same in both surveys (identities are not known by evaluators), lending to the parallel results.

Table 10. NOVA Labs marketing (surveyed teachers)

Learned about NOVA Labs	Count Cloud Lab Users	Count All Users
Link on the NOVA Education website	13	21
NOVA Education newsletter (SPARK)	10	18
An internet search	3	6
NOVA Education online webinar	2	4
NOVA social media (Facebook, Twitter, etc.)	3	3
NOVA booth at a conference	1	2
NOVA Labs brochure or print material	1	1
Word of mouth – recommended by a friend/colleague	0	1
Other: NSTA	1	n/a
Other: NC Climate Fellows Noodle	n/a	1
A live presentation by NOVA Education staff	0	0
n=	21	37

Respondents could select more than one answer.

Results

Cloud Lab in Practice

The majority of *teachers interviewed* (four of the five) and *surveyed* (nine of 21) used the Cloud Lab as part of their weather unit. See Tables 11-13. For the Cloud Lab users, it was mostly employed with 6th grade students (10 of the 21 teachers). The rest of the distribution was primarily in middle and high school grades; with fourth grade the lowest level to have used it.

Some more unusual subject uses were reported, as well. One grade 8 *interviewed teacher* used it as part of a physical science unit on phase changes, using weather to illustrate the phase changes, particularly in the water cycle. This teacher shared that her students take atoms for granted, because they can't see them; but weather, particularly clouds, illustrates the phase changes. Additionally, she is in an area of California that has been in a drought for years and her students rarely see rain clouds. By using the Cloud Lab to teach phase changes, she connected something abstract (atoms) to something to which students can relate. She also plans to connect the Cloud Lab to climate change in Earth Science class. Additionally, two *surveyed teachers* used the Cloud Lab to teach volcanos and stoichiometry.

Table 11. Subject focus of unit in which Cloud Lab was used (interviewed teachers)

	Grade(s)	Subject Focus
Class 1	8	Physical Science/Phase Changes
Class 2	7	Earth Science/Weather
Class 3	5	General Science/Weather
Class 4	7	Earth Science/Weather
Class 5	8	Earth Science/Weather

Table 12. Grade levels with which Cloud Lab was used by surveyed teachers (n=21). Teachers could select more than one grade level.

Grade with which Cloud Lab was Used	Frequency
4	1
5	3
6	10
7	4
8	4
9	4
10	4
11	5
12	4
Post-secondary	1

Table 13. Subject focus of unit in which Cloud Lab was used (surveyed teachers)

Subject Focus	Frequency
Earth Science/Weather	9
Volcanos	1
Stoichiometry	1
Ocean/Atmosphere	1

The majority of teachers (interviewed and surveyed) completed the Cloud Lab during class time. See Table 14 and 15. All five *interviewed teachers* and the majority of the surveyed teachers (10) reported using Cloud Lab with their students in the classroom. Beyond this, however, there was no consensus on the implementation. *Surveyed teachers* worked with students in three ways—three completed Cloud Typing as a large group, four completed it with small groups/pairs, and four had students work alone. Surveyed teachers were more likely to use Reconstruct A Storm with small groups or individuals.

Of the four *interviewed teachers* who used Cloud Typing, three used it as a contest. The teacher with only one computer in her classroom formed student into teams; one at a time, each student would come to her desk and choose a cloud type. This was projected on a screen for the rest of the class. If a student was unsure of the cloud type, they could ask an "expert", a student who had a better understanding of cloud typing, if they agreed. She encouraged conversations among the students and teams. Another teacher who used the Cloud Typing challenge explained that each class had a goal to get a certain number of points. She felt the kids enjoyed the competition, as this school, a private school, does not give grades or points.

Table 14. Class use of Cloud Lab (interviewed teachers)

Class	Videos	Cloud Typing	Reconstruct A Storm
1	Watched as Class	Competition, One Child at a Time on Teacher's Computer in classroom	Watched Inside a Megastorm as Class
2	Watched as class	Did Not Use	Worked in Pairs
3	Watched as class and individually	Competition, As individuals on their own computer	Hurricane Sandy and Cyclone Evan as class, Nadine and/or Isaac on their own
4	Watched as Class	As individuals in computer lab	Watched Inside a Megastorm as class, worked on Analysis if time permitted
5	Watched alone	Competition, As individuals or in small groups	Small groups

Table 15. Class use of Cloud Lab (surveyed teachers)

Student Work	Cloud Typing	Reconstruct A Storm
Large Group	3	1
Small Group	4	3
Individuals	4	3
Homework	1	1
Extra Credit	0	1
n=	11	8

All five *interviewed teachers* showed the videos. Due to available technology, three teachers watched the videos as a class, one had students watch some videos as a class and others individually, and the fifth had students watch alone. The Cloud Typing challenge was used by four of the five interviewed teachers with their students. All five teachers used Reconstruct A Storm: Inside a Megastorm. Several of these teachers felt Reconstruct a Storm: Inside a Megastorm was important because students remembered hurricane Sandy.

Four of the five *interviewed teachers* used Reconstruct A Storm Analysis with their students, the fifth allowed students who completed the Cloud Typing challenge to move on to Reconstruct A Storm Analysis while other students completed the Cloud Typing challenge. One teacher had her students complete the Open Ended Reconstruct A Storm Activity, another allowed students to start if time permitted.

Table 16. Cloud Typing Activities Completed By Class (interviewed teachers)

Class	Videos	Cloud Typing	Reconstruct A Storm: Inside a Megastorm	Reconstruct A Storm (Analysis)	Reconstruct A Storm (Open-Ended)
1	Yes	Yes	Yes	No	No
2	Yes	No	Yes	Yes	Started, ended due to time constraints
3	Yes	Yes	Yes	Yes	No
4	Yes	Yes	Yes	If finished w/ Cloud Typing	No
5	Yes	Yes	Yes	Yes	Yes

Of the 21 *teachers surveyed* who reported using Cloud Lab with their students, **15 reported using at least one of the videos, 12 shared they completed Cloud Typing, and eight completed at least one of the three activities of Reconstructing a Storm**. See Table 17 for complete breakdown of Cloud Lab use. Only two of the 21 surveyed teachers who used Cloud Lab indicated their students completed the Lab Report.

Table 17. Cloud Lab individual component use (surveyed teachers)

	Frequency
Video: Clouds and Severe Storms	10
Video: The Making of a Cloud	9
Video: Clouds and Weather	9
Video: Hurricane Rotation and the Coriolis Effect	9
Video: Why So Many Cloud Types	8
Video: The Climate Wild Card	6
Cloud Typing Key	10
Reconstruct a Storm: Inside a Megastorm	7
Reconstruct a Storm: Analysis	5
Reconstruct a Storm Open Ended	5

Student Outcomes

Interpreting Scientific Data/Tools

***Teachers surveyed* believed that using Cloud Lab in their classroom increased student knowledge of key meteorology concepts and improved their ability to read, analyze and interpret data visualizations**. See Table 18. More than half of the Cloud Lab users responding to the survey reported that they "strongly agreed" that students had achieved the following due to Cloud Lab use:

- Increased knowledge of key concepts of weather or meteorology
- Improved ability to read data visualizations
- Improved ability to analyze and interpret data or visualizations
- Improved ability to make observations from data

Four of the five *teachers interviewed* reported students were more comfortable with graphical representation of data after completing the Cloud Lab. Additionally, several *interviewed teachers* reported students were more patient with the data, taking time to read it and helping each other make sense of it. One teacher shared her students were intimidated by the visualizations in the pre-questionnaire, so she reviewed them with her students before they viewed *Reconstruct a Storm: Inside a Megastorm*. One teacher wished she had more time with *Reconstruct A Storm* (students that finished Cloud Typing moved to Reconstruct A Storm if time permitted). She felt *Reconstruct a Storm* *"forces the kids to think about the data they are seeing. They realize that data is easier to use."*

Table 18. Surveyed teachers feelings about student benefits from Cloud Lab

n=15	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
Increased knowledge of key concepts of weather or meteorology			2	4	9
Improved ability to read data visualizations.			1	6	8
Improved ability to analyze and interpret data or visualizations.			2	5	8
Improved ability to make observations from data.			2	5	8
Demonstrated ability to ask scientific questions			5	5	5
Demonstrated ability to plan and carry out an investigation			5	6	4
Demonstrated ability to use mathematics and computational thinking.			6	6	3
Increased understanding of role of engineering.		3	3	5	4
Became more aware of careers in STEM (science, technology, engineering, or math).		2	3	5	5

Teacher observations were confirmed by results of student pre/post-tests in the five test classrooms in this study. The pre/post-test was a set of 10 forced-choice and short-answer items were administered to assess students' knowledge and skills in the targeted areas. In scoring, each question was assigned a point-value. Forced-choice items received a score of 1 for a correct answer, or 0 points for an incorrect answer or skipped question. Short-answer items were scored on a rubric of 0 points for an incorrect answer or skipped question, 1 point for a basic correct answer (i.e., gave one correct explanation), and 2 points for an extended answer (i.e., gave two correct explanations). Scores for items were summed to reach a total skill-score for each student (at pre and at post). A score of 10 indicated correct answers on all questions, with a maximum possible score of 13 (if advanced answers were given on open-ended questions).

Student test data were analyzed three ways. For the entire data set, the percentage of students with the correct response (a score of 1 or 2 on open-ended questions) were calculated for the pre and post conditions, and the unpaired data compared descriptively (see Table 19). Secondly, for each student in each condition, a total score was calculated from all of the skill-based questions. Finally, paired pre/post data of total scores were analyzed using a paired-samples t-test.

Of the 321 pre-questionnaires and 298 post-questionnaires completed by the students in the five schools, there were 260 valid pre-post pairs. The data were analyzed to ascertain shifts in student ability to read and infer meaning from data visualizations related to weather and meteorology. See Appendix for complete paired t-test results.

Overall, the pre-post test results indicate a positive shift in student ability to read and infer meaning from data visualizations related to weather and meteorology. Taken together, the average score in the pre-test condition was 4.5 out of 10 points (a basic correct maximum); after the Cloud Lab, the post-test scores increased to a mean of 5.93. This was a statistically significant increase of 1.43 points in ability scores (t= 11.06, df=259, p<.001). Figure 1 illustrates the increase in students' total correct number of responses from pre- to post-test; the blue and green bars each form a normal distribution, but with the mode score at 4 of 10 in pre, and 7 of 10 in post.

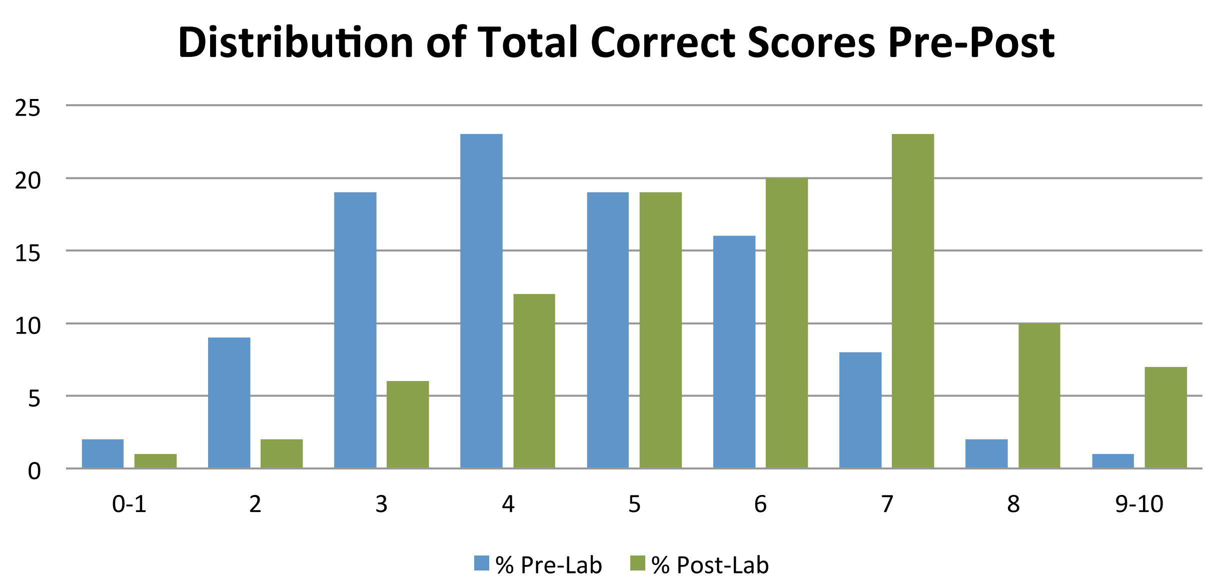

Figure 1. Distribution of total correct scores pre and post-lab

Looking at each test item individually, a greater percentage of students identified the correct response on the post-test for eight of the ten questions (Table 19). The change appeared to be greatest for questions regarding the reading and interpretation of the graphs; with the greatest pre/post-test increase (31 percentage points) for the questions regarding cloud height from a graph.

Table 19. Comparison of pre- and post-test results for student questionnaire

	% of Sample Answered Correctly		
Question Topic	Pre (n=321)	Post (n=298)	Change
Read Graph: Cloud Height	47%	78%	+31
Open Ended: Why is it important for meteorologists to know the temperature of cloud tops.	27%	52%	+25
Read Graph: Rate of Rainfall	17%	37%	+20
Cloud Identification: Cumulus	51%	67%	+16
Open Ended: What meteorologists figure out from a data visualization illustrating cloud structure.	33%	48%	+15
Open Ended: Importance for meteorologists to identify different types of clouds	80%	94%	+14
Read Graph: Cloud Temperature	87%	92%	+5
Cloud Identification: Stratocumulus	39%	43%	+4
Type of Weather Associated with Cloud	14%	14%	0
Cloud Identification: Nimbostratus	49%	46%	-3

Statistically, when paired pre/post data were compared at the individual question level, analysis showed that statistically significant positive gains were noted for six of the 10 individual items:

- Cloud Identification: Cumulus (t= -4.057, df=259, p<.001).
- Read Graph: Rate of Rainfall (t= -6.959, df=259, p<.001).
- Read Graph: Cloud Height (t=-8.858, df=259, p<.001).
- Importance for meteorologists to identify different types of clouds (t= -6.504, df=259, p<.001).
- What meteorologists figure out from a data visualization illustrating cloud structure. (t= -4.342, df=259, p<.001).
- Why is it important for meteorologists to know the temperature of cloud tops. (t= -6.534, df=259, p<.001).

Success and Usability of Working with Data: Teacher Reports

The majority of *teachers surveyed* (17 of 19) believed the Cloud Lab content was about right for students' grade level, which is amazing due to the wide-range of grades in which the Cloud Lab was used (grade 4 – post-secondary). They also felt it was about right for students in terms of content addressed, tasks required, and complexity of the material (Table 20). These teachers overwhelmingly agreed that their students responded positively to Cloud Lab's videos (15 of 15), activity-based structure (14 of 15), and game-like design (13 of 15). Competition with students was generally the most neutrally-responded to item in this question, indicating it was not the most compelling of its attributes. See Table 21.

Table 20. Surveyed teachers' feelings about Cloud Lab fit with students

n=19	Far below students' level	Somewhat below students' level	About right for students	Somewhat above students' level	Far above students' level
Grade-level fit			17	2	
Content addressed			16	3	
Tasks or skills required of students			14	4	1
Complexity or depth of material covered			13	5	1

Table 21. Surveyed teachers' feelings that students had a positive response to specific aspects of the Cloud Lab

n varies between 14 -15	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
Activity-based structure			1	3	11
Addressing a relevant/real issue			2	2	11
Interactive design				5	10
Using real scientific data			2	3	10
Game-like design			2	3	10
Videos providing content				7	8
Competition with other students			6	2	7

Additionally, the majority of *teachers surveyed* believed students struggled very little to not at all while navigating the site (13 of 15), using the data viewing tools (10 of 15). understanding the goal of the lab activity (10 of 15), and knowing what to do within the steps of the lab activity (10 of 15). There appeared to be more struggles around finding answers to their problems or questions: finding answers about how to use the interface (6 of 14) and finding answers about the content of the lab (7 of 15). See Table 22.

Table 22. Surveyed teachers' feelings about students' struggles in using Cloud Lab

n = 15	Did Not Struggle at All	Struggled Very Little	Struggled Somewhat	Struggled a Great Deal
Navigating the site overall	6	7	1	1
Using the data viewing or analysis tools	5	5	5	0
Understanding the goal of the Lab activity	2	8	4	1
Knowing what to do within the steps of the Lab activity	3	7	5	0
Finding answers about how to use the interface	4	5	6	0
Finding answers about the content of the Lab	5	3	7	0

One indicator of success for Cloud Lab was teachers' reports of whether a majority of their students could be successful with the activities in the Lab. Student success reported by *surveyed teachers* varied considerably, as illustrated by Table 23**. Most of the Cloud Typing users (9 of 11) reported the majority or more of their students were successful with the activity; and just over half (5 of the 8) of the teachers who used Reconstruct A Storm reported that 50% or more of their students were successful.**

Table 23. Surveyed teachers report of student success

Approximate % of students who were successful:	Cloud Typing (n=11)	Reconstruct A Storm (n=8)
All of my students were successful	1	0
75% or more	3	3
50% - 74%	5	2
25-49%	2	2
Less than 25%	0	1

Among the test group teachers, **the five teachers interviewed reported various levels of student success with the Cloud Lab, from 35% of students being successful to 90% of students being successful. *Interviewed Teachers* who completed Reconstruct A Storm analysis reported a student success rate of 50 – 75%.** The large variance is possible due to different activities, students' grade, prior science knowledge, and teachers scaffolding of the materials. While one teacher believed 35% of her students were successful with Cloud Typing, she also believed another 30% were encouraged to try more. She shared that some of her students were interested and others weren't because the "didn't want to do anything weather." Another teacher, whose students worked as pairs to complete the Lab, felt up to 75% of her students were able to complete the activity successfully, and felt students were more engaged as long as they understood it.

One teacher shared that using the NOVA Cloud Identification activity gave her "much better results" than the method she used last year which she described as consisting of:

"[watching] a couple of clips on clouds,…" and trying "to identify clouds outside, which is always good theory, but you don't see all the types of clouds in WI within a month that actually exist."

All teachers interviewed were able to cite something that their students learned or were able to do because of Cloud Lab, including:

- A better understanding of variables affecting storm formation, growth, decay.
- More comfortable with graphical representation of data that looked different to them.
- They were more patient, take time to read the data, worked well helping each other.
- A better understanding of the interaction of hidden things, like condensation and the way the wind moves, why there is weather.
- This helped students with patterns, how things build on each other, relationship between temperature and how condensation happens.
- What a real meteorologist deals with; it is good for students to understand how complex it is, but it's accessible to them.

Success and Usability of Working with Data: Student Reports

The majority of students also self-reported the Cloud Lab was easy to use and they were able to easily interact with the interfaces. See Figure 2. Students were most likely to report that it was easy or very easy to: know the goal (69%), know what to click (62%), and know when you were done (60%). **Knowing where to start and knowing where to get help were the two areas that were relatively more difficult for students.** This echoes teacher data reported above.

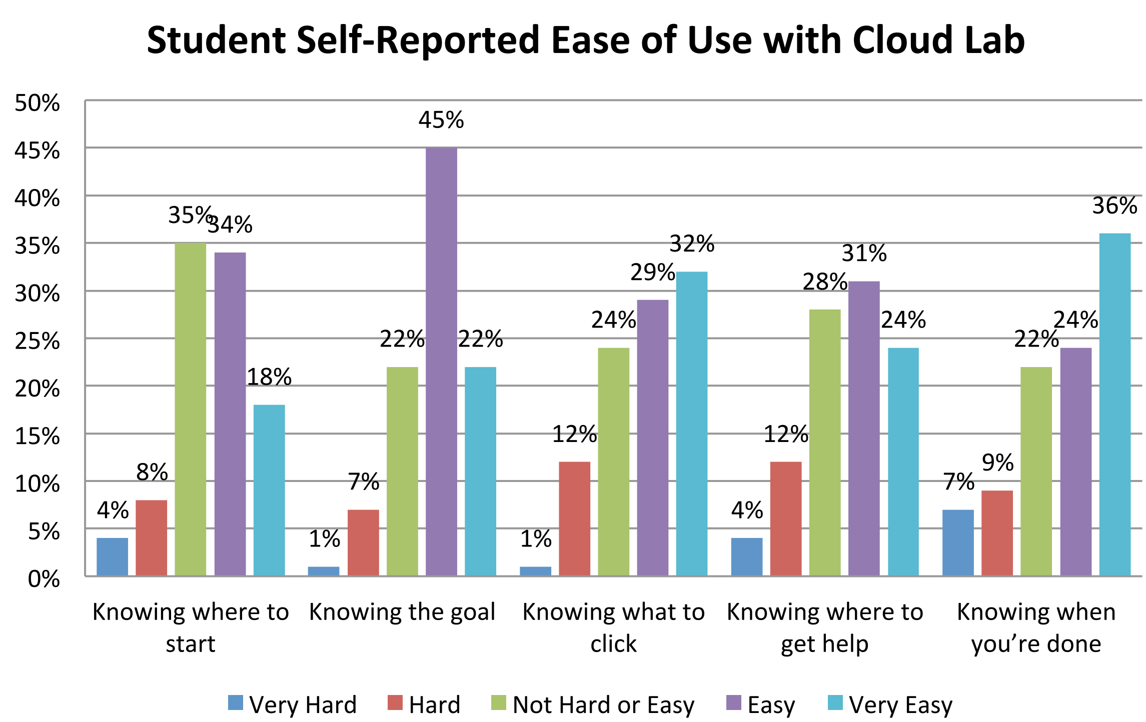

Figure 2. Student Ability to Use Cloud Lab (n varied from 218-290)

The **majority of students self-reported they felt they were somewhat or mostly successful in doing the activity assigned**. See Table 24. Fewer of the students selected "totally successful" (between 11% and 29%), indicating some challenges in the activities. The number of responses differs because only the data from students whose teacher indicated they completed a particular activity were included in the analysis.

Table 24. Student self-reported success with Cloud Lab

	Not at all Successful	Not Successful	Somewhat Successful	Mostly Successful	Totally Successful	Did Not Do
Cloud Typing (n= 260)	5%	10%	36%	29%	14%	3%
Reconstruct A Storm Analysis (n= 98)	3%	5%	25%	38%	29%	1%
Reconstruct A Storm Open (n=19)	5%	-	42%	42%	11%	-

Students were also asked to rate the Cloud Lab in comparison to their usual schoolwork. **The majority of students (61%) self-reported they liked doing the Cloud Lab *a little* to *a lot more* than usual schoolwork**, see Figure 3. Only 20% reported that they liked it less than usual schoolwork; and about 18% thought it was about the same.

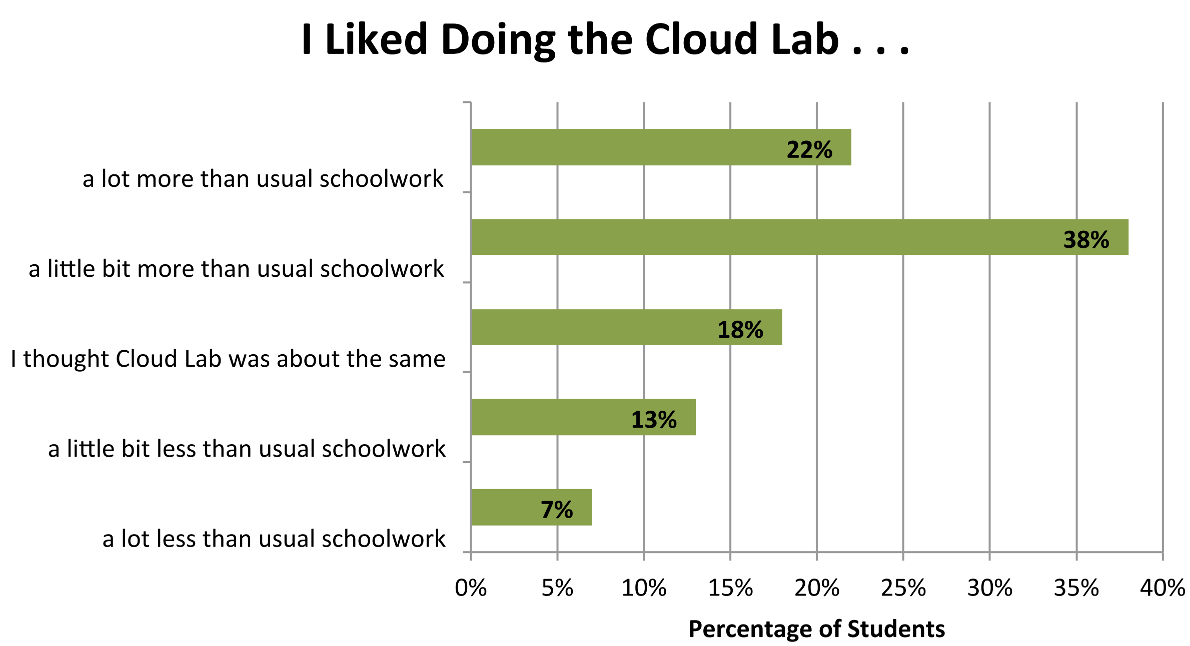

Figure 3. Student comparison of Cloud Lab to schoolwork (n=293)

The 179 students who liked doing the Cloud Lab a little or a lot more than usual schoolwork reported that they gave it this rating because:

- It was fun (34%)
- They learned something new about clouds, storms, weather (33%)
- It was different than typical schoolwork (22%)
- It was active (9%)
- It used a computer (8%)

The 60 students who liked doing the cloud lab a lot less or a little bit less than usual schoolwork reported they gave it that rating because:

- Not interested in general (19%)
- Not interested in the content (17%)
- They found it difficult (12%)
- They didn't understand it (8%)
- It wasn't active enough (8%)

Slightly more than half of the students (54%) surveyed would use the Cloud Lab, or another NOVA Lab, for a school project, while 34% of the students reported they plan to continue exploring it, or another NOVA Lab on their own. Additionally, 24% of the students plan to tell a friend about the Cloud Lab, or another NOVA Lab.

Engagement and Interest with Real Data

The majority of *surveyed teachers* (13 of 15) believed that students respond positively to using real scientific data. The *interviewed teachers* responded similarly, but also noted that **they were already using real scientific data when it was available and appropriate.** Of the 295 students who responded to the question about how often they use real scientific data in their classroom, students confirm they are aware of this use by their teachers in the classroom; only 5% believe they never use real data.

Of the students surveyed, 57% were aware they were working with real scientific data in the Cloud Lab; an additional 30% thought it might be real scientific data, but they weren't sure. Only 11% of those surveyed admitted they were unaware they were using real data. This indicates the Lab did a good job of communicating this information within the context of the activities.

The vast majority of students (83%) reported a preference for engaging with real data. Representative comments from students preferring real data include, but are not limited to:

> *"It's nice to see what the scientist are studying and figuring it out like them makes me feel smart that I can figure out the data like they can."*
>
> *"I enjoy using real data that way I know I'm learning from a credible source."*
>
> *"I like it, because . . . we know . . . what we might be dealing with if some of us become scientists."*
>
> *"It's really cool because as adults when we watch the news we actually know what the heck the news reporters are talking about. As an athlete I can know what kind of weather will be and what clothes I should wear to games and practices."*

> *"I think that it could be helpful to understand the concepts we are learning, but sometimes I thought their work was way more complicated than the work we were doing so it was sometimes confusing."*
>
> *"I like it because . . . I can talk about it with my parents."*

Students who indicated they did not have preference about engaging with real data (14%), shared it doesn't matter if the data is real or not because they still get practice with the concept.

Finally, 3% of students did not want to use data from real scientists. Representative comments from those students include, but are not limited to:

> *"Well I kind of don't like it because it will be like stealing it."*
>
> *"I don't enjoy using other information because I think we should measure things ourselves to get more unique results."*

The majority of *surveyed teachers* (12 of 15) believed that students were more engaged in the Cloud Lab compared to other teaching strategies. Providing context to this, of the five *teachers interviewed*, three believed their students had above average levels of interest and engagement in the Cloud Lab activities. One teacher shared "no one was asleep." They were "right with her through the class," and that she had no behavior issues. Another teacher shared the students were more engaged, as long as they could understand it. The two remaining teachers indicated their students had a normal level of engagement with the Cloud Lab; one shared "some kids were interested, others didn't want to do anything weather." This again corresponds to the self-reported data from the students.

Teacher Outcomes

Success and Usability of Materials

All five *interviewed teachers* were successfully able to deploy videos, introduce and facilitate the Cloud Typing challenge, and facilitate the Reconstruct A Storm analysis. Teachers who had difficulty with technology found ways to work around those issues before introducing the Cloud Lab to students. Technology challenges addressed prior to implementation included slow-processing computers, networked computers, and school security filters.

All teachers loved the videos. As with previous evaluation results of NOVA Labs offerings, the videos continue to be one of the strongest parts of the site, from the perspective of teachers. *Interviewed teachers* commented that they were "beautifully shot" and contained "great" content. One teacher commented on the length of the videos:

> *"It is key when dealing with middle school students; they focus better on short videos."*

Additionally, one teacher shared that her students liked having the transcript of the videos; this allowed them to read along and ask questions about words they didn't understand. *Interviewed teachers* shared **some students experienced difficulty getting to the second video in a set.** The statement "Field is Required" did not stand out in the assessment questions to realize that they were expected to answer the question to find the next video.

Table 25 illustrates surveyed teachers' positive thoughts regarding the videos. All teachers rated all aspects of the videos good or very good; with the majority of teachers rating them very good. Teachers in comments noted that there is a value in finding "great visuals to explain a science concept." One surveyed teacher shared:

> *"I've been teaching students how clouds form for 17years ~ using drawings, examples, observations, mini-labs ~ but the sketched out animation of how clouds form was fantastic! More students understood it quickly than any other method used, even the hands-on experience of forming a cloud in a bottle."*

Table 25. Surveyed teachers feelings about Cloud Lab videos

n=15	Very Poor	Poor	Fair	Good	Very Good
Professional quality of materials				4	11
Easy for me to apply in the classroom				5	10
Engaging for students				5	10
Enough scaffolding for students to use				7	8

***Interviewed teachers* reported the Cloud Typing challenge was successful for several reasons**. Both teachers and students commented about the scenic beauty of the cloud pictures. Students either wanted to go to the national parks where the pictures were taken or shared they had been to the parks they saw in the pictures. This added element of connection made the activity "more real" for the students who had visited the parks because they "had seen those land forms."

> *"Cloud typing has stuck with them, . . . they will come into my room and if we have clouds outside, they will sit there and debate for five minutes what type of cloud is out there. This turns into a pretty good discussion" which increase their critical thinking skills. They aren't just seeing clouds as big puffy white things in the sky anymore they understand that clouds are at different heights and they are shaped like this because of what is going on in the atmosphere, they are looking at hows and whys instead."*

Two *interviewed teachers* pointed out there were cloud types in the activity that were not usually visible in their part of the country. One teacher also pointed out that Cloud Typing challenge was convenient, "real" weather is not. ***Interviewed teachers* found the following challenges with cloud typing** — a confusing point system, challenges accessing individual students' progress, and appropriate scaffolding.

Surveyed teachers were generally pleased with the Cloud Typing challenge, but ratings were not quite as high as they were for the videos (Table 26). More than half of the teachers who used Cloud Typing reported the activity was "very good" at being engaging for students (8 of 11) and easy to apply in the classroom (7 of 11). The lowest ratings, relatively, was about provision of enough scaffolding for students to use, to which 7 of 11 teachers ranked it as "good," (which is still positive, but the lowest ratings in this sample). It is worth noting that this echoes results from earlier Energy Lab feedback from teachers that scaffolding was the area slightly lagging behind other strong qualities of the Lab.

Table 26. Surveyed teachers feelings about Cloud Typing challenge

n=11	Very Poor	Poor	Fair	Good	Very Good
Engaging for students				3	8
Easy for me to apply in the classroom			1	3	7
Professional quality of materials				6	5
Enough scaffolding for students to use				7	4

The Cloud ID Key was not used consistently among *interviewed teachers*; only one teacher believed her students used the key to its full potential. One eighth grade teacher shared that some students used it, some didn't. She believed that even with the key, it was still difficult to identify some of the more complicated clouds. The fifth grade teacher believed the key was hard to use and when you pulled it up it covered up some of the clouds the students were trying to identify. She had her students make their own cloud ID keys and incorporate it into their science notebook. While developing their own key, the fifth graders realized that the clouds had the same root words which helped them better understand cloud identification.

As illustrated in Table 27, surveyed teachers who used Reconstruct A Storm in their classrooms (n=8) **were positive about the Reconstruct A Storm activities. *Interviewed teachers* believed Reconstruct A Storm: Inside a Megastorm was successful because students remembered hurricane Sandy and made a real-world connection**. One teacher thought Inside a Megastorm "was a great way to start" the lesson "and that engaged them"; she could "see them honestly hungry for more" after the Inside a Megastorm activity. One teacher showed the class Inside a Megastorm to introduce the models because her students "were intimidated by the models" in the pre-questionnaire. Her students worked with other students and the teacher to make sense of the models. One teacher compared this site to NASA "Whirlwind" for replaying storms and believes Reconstruct A Storm is easier to use. Three teachers <u>would like to view more types of storms,</u> including snow storms and tornados.

Table 27. Surveyed teachers feelings about Reconstructing a Storm challenge

n=7-8	Very Poor	Poor	Fair	Good	Very Good
Engaging for students				2	6
Professional quality of materials				3	4
Easy for me to apply in the classroom				4	4
Enough scaffolding for students to use				4	4

***Interviewed teachers* who used Reconstruct A Storm: Analysis & Reconstruction shared that their students needed to work through at least one storm before they understood it.** One eighth grade teacher did not understand why it was difficult for her students, as "it seemed very concrete and clear cut" to her. She suggested forcing students to click on Cyclone Evan first, as it was the easiest storm and the best place to start. One teacher said her students utilized the tag system and pop-up windows to guide them through the activity and that worked well. Teachers would like more storms to give students more opportunity to practice.

Only one *interviewed teacher* (Grade 8) asked her students to complete the Open Investigation, which she reported was challenging for her students. Her students didn't understand what they were supposed to do. Instead of a blank map, she suggests scaffolding with some directions or adding a sidebar with links that allow students to refer back to necessary information. Additionally, students need something to explain the buttons and overlays, maybe a similar tag system and pop up window as Analysis & Reconstruction.

Impact of NOVA Labs on Teaching Science

Using the Cloud Lab impacted the teachers interviewed in several ways, including:

- **Increased their use of technology with their students**
- **Altered their teaching methods from prior years**
- **Altered the content they used to teach a concept.**

The majority of teachers surveyed reported at least some change to their overall approach to teaching weather (12 of 17), use of technology (11 of 17), type of content included (10 of 17) and incorporation of data from scientists into the unit (13 of 17)

One interviewed teacher, with minimal technology access, shared that she did a lot more on the computer "than we normally would." Several teachers gained a better understanding of technology as they worked to overcome computer and internet security challenges imposed by their school. Another interviewed teacher's computer was upgraded as she was having difficulty accessing the website and another teacher overcame scheduling challenges with the school's computer lab in order to use the Cloud Lab.

Several interviewed teachers changed their pedagogical approach to weather when they used Cloud Typing as a contest with their students. Another presented the Cloud Lab as a starter lesson, letting the "kids do it on their own"; she wanted the students to develop independent learning skills. One teacher would have used her textbook if she hadn't participated in this study. Finally, one teacher altered the content they used to teach a concept, she would not have connected clouds to atoms if not for this opportunity.

Satisfaction with NOVA Lab and Interest in Further Use of Data

These teachers appear to be satisfied with Cloud Lab. All teachers interviewed and surveyed are either *somewhat* to *very likely* to use the Cloud Lab next year. Additionally, the majority of teachers surveyed (All Respondents) are also somewhat or very likely to use the Energy Lab (21 of 21) and Sun Lab (25 of 25). An *interviewed teacher* from California thought it was:

> *"Interesting that at just the time we were finishing, we got some actual clouds in the sky. California is famously sunny, and we've been in a drought for about three years now, so my students are not very accustomed to looking at the sky and seeing anything of interest. This changed all that! Several reported being somewhere - soccer practice, in the car en route to some activity - and looking up and applying what they'd just learned."*

Another *interviewed teacher* had already taken steps to incorporate other NOVA Labs in her classroom, sharing that a gifted and talented student was going to work on the Energy Lab while the rest of the class did a lab he had already mastered. **Another teacher planned to recommend the Sun and Energy Lab to other teachers who have those topics in their curriculum**.

All five teachers interviewed are interested in incorporating real scientific data into classroom lessons. They are currently incorporating real data into science lessons using NASA websites, JASON project, CIESE.org, and Google Earth. When asked about use of "real data," one teacher shared that her students would be "confused if they were presented with hypothetical data". Her students gather their own data through science experiments, including water quality testing and raising salmon. One teacher had used a different web-based activity to teach weather last year. She shared that her students used:

> *"a different model last year, they were supposed to be reconstructing a hurricane, there was zero real data, everything was made up, it wasn't even taking place in a real town." [Her students] "understood why I was having them do it, but it didn't mean anything to them, that website will never be used again. It did not stick. I know that seeing real footage of [storms] made a bigger impression than any other resource that I used before." ... "real data makes it more concrete for them."*

Feedback for Further Improvement

Because NOVA Labs is a platform, upon which future iterations of Labs and topics are able to be developed, formative feedback about technical, pedagogical, and content-related considerations were part of the evaluation analysis. Ideas and themes that emerged from the survey and interview data are summarized here for consideration by the NOVA Education team.

Log-in and Technology Infrastructure

- An interviewed teacher had a challenge with the log in. She couldn't log into Cloud Lab from the PBS NOVA site (where she was already logged in).
- Students that were logged in as guests were "kicked off the site", according to one interviewed teacher.
- Logged in students should be able to save points and return at a later date.
- Make the "Submit" button more obvious as students shared they had trouble finding it.

Videos

- An interviewed teacher shared that students didn't realize that you had to put something in the text box (or answer the question) to move to the second video. The "Field is Required" doesn't stand out.

Cloud Typing

- Interviewed teachers expressed a desire to have a transparent point system. Teachers and students competing for points did not understand how points were awarded.
- An interviewed teacher was confused on how to access individual student's progress (all students were on guest log in).
- Interviewed teachers in grades 5 and 8 needed to scaffold the content of Cloud Typing for their students. One teacher suggested beginning Cloud Typing with the three basic clouds.

- Teachers and students found it difficult to determine the cloud height in several pictures and wondered if there was a better way to illustrate the cloud height.
- Interviewed teachers believed the Cloud Identification key should be changed to a dichotomous key to help students better understand the key factors of cloud types

Reconstruct A Storm

- Interviewed teachers expressed an interest in more storms of different types, including snow storms and tornados.
- Interviewed and surveyed teachers believe that in order to increase student understanding of the analysis, students should be forced to begin with a simple storm and answer questions correctly before moving on.
- An interviewed teacher would like the following additions to the Open Investigation: add a sidebar with links that allow students to refer back to necessary information; explain the buttons and overlays, maybe a similar tag and pop up window system as that used in Analysis.

New Topics

- Surveyed teachers were asked to suggest possible topics for upcoming NOVA Lab projects, greatest interest was in Geology (9), followed by Biology (5), Physical Science (5) and Astronomy (4)

Lab Report

- A surveyed teacher would like everything students do while in the lab recorded to avoid confusion.

General

- Students shared they had difficulty understanding where to start and didn't always realize when they were finished with an activity.
- An interviewed teacher would appreciate an opportunity for teachers to share information about how they are using the Lab with students.

Discussion and Conclusions

Overall, the Cloud Lab was successful at achieving its goals with the teachers who used it in the Fall 2013 semester. The Lab was primarily used by middle and high school grades, with 6th and 7th grade seeming to be a key grade interested in Cloud Lab (perhaps aligning with curriculum standards for teaching weather).

The results presented here showed that students were able to achieve the three primary outcomes. **Overall, students were successful working with the real data provided in the Cloud Lab.** Students reported generally feeling successful with the Lab activities they did, although feeling a degree of challenge that may not have made them feel extremely successful. Similarly, teachers tended to report that the majority of their students were able to be successful with the activities; although this was more true of the Cloud Typing than Reconstruct A Storm. However, teachers certainly believed that the Cloud Lab content was "about right" for the students at their grade level.

Data also indicated that use of Cloud Lab increased student knowledge of key meteorology concepts and ability to read, analyze and interpret data visualizations related to the Lab's content. Students appeared to demonstrate the greatest growth in their ability to interpret and use scientific data. This was confirmed by teachers who reported students were more comfortable with graphical representation of data after completing the Cloud Lab.

The results also showed that students were engaged and interested in the Cloud Lab and its use of real data, with most reporting they liked it better than "usual school work," reporting they were aware they were using real data in Cloud Lab, and reporting they liked using real data in school. Surveyed teachers strongly agreed that students responded well to the fact that Cloud Lab addressed a relevant/real issue, had an activity-based structure, and used a game like design. These results echoed earlier evaluations of other NOVA Labs.

Among the secondary audience of teachers, there was evidence that the key outcomes were also achieved. **Teachers in this sample were able to successfully incorporate the Cloud Lab into their lessons,** although only a relatively small number of teachers (26 total) were able to be identified by NOVA Education and evaluators as having used Cloud Lab so far. The teachers reported many positive attributes of the Cloud Lab and its quality for their use. As with prior evaluation of Sun Lab and Energy Lab, teachers report the videos in the Labs are an incredible strength. Lab activities are also strong, but are generally the areas where there are more critiques and suggestions for further development. **A theme that was seen in these data, and echoes earlier findings of the Energy Lab, was that increased scaffolding for student engagement with the Lab is needed**. Particularly as activities get more open-ended, such as the Open Investigation, teachers found students had increasing trouble getting started, navigating, and knowing what to do.

Teachers in the test-group classrooms had already had experience incorporating real data and scientific processes in their lesson plans wherever possible; this **pre-existing enthusiasm for data in the classroom may be a common attribute of many teachers who come to NOVA Labs**. However, even with prior experience, these teachers were impressed with Cloud Lab and plan to continue using it with their students. **The majority of surveyed teachers indicated they experienced "some change" to their overall approach to teaching, use of technology, and incorporation of data from scientists.** They rated the quality of Cloud Lab videos, Cloud Typing, and Reconstruct a Storm highly and plan to continue using Cloud Lab with their students.

To contextualize these results, it is worth noting that this study involved a relatively small sample of teachers and smaller number of identified users of the Cloud Lab. The five test-classrooms identified provided rich sources of data to study the extent to which the Labs were effective with students. However, questions may remain about the breadth of NOVA Labs usage in classrooms. An increased ability by NOVA Education to identify the number of users of Labs may be valuable, if technologically feasible, in future study or documentation of impacts due to this rich set of resources for teachers and students.

Recommendations

Based upon the findings and feedback resulting from this study, a few recommendations emerged for consideration by the NOVA Labs team as they develop future NOVA Lab environments. These recommendations are informed by the data from the Cloud Lab study, specific recommendations that were heard; recommendations bring an emphasis on those themes that were reminiscent of findings and recommendations from studies of earlier Lab content areas.

- Consider adding additional information to the Educator Guide to ensure teachers know how to best scaffold the lab for their student's abilities and knowledge. Teachers in a wide grade band use Cloud Lab, and as the program may reach out to a broader range of teachers (perhaps with less experience using tools like this), greater amounts of support and ideas for implementation may support a broad reach.

- In the Cloud Typing challenge, consider identifying the cloud height in images to support students in identifying images. At times, the perspective of the photos was reported to limit the students' ability to judge this characteristic. In future Labs, looking for elements of challenges that might be difficult to interpret without additional context may be advised.

- In support of the Cloud Typing challenge or future Labs that may use an identification-type key as part of the work, consider modifying the Cloud Identification key to be a dichotomous key format; some teachers reported this being a more familiar format for students.

- In the Reconstruct A Storm challenge, consider including more and varied types of storms. Additional storms would provide students more practice reading data visualizations and access to diverse weather conditions which they may not typically encounter due to geographic limitations. For future Labs, it seems that the greater number of individual examples or activities within a type of Challenge would be valuable to teachers and students. Often, it requires practice and advancing through levels of difficulty for students to reach a better level of understanding the concepts. Having more structured options to do would be a benefit for teachers and learners.

- In future Labs' design, an ever-increasing focus on creating activities and challenges around an "average student-user" is advised. Growing from multiple evaluations of Labs, there has been repeated focus by teachers on the need for more scaffolding of activities to increase student understanding. In Cloud Lab, students sometimes had difficulty understanding where to start or finding answers to questions. In very specific examples, students had difficulty finding the "Submit" button and didn't always realize they needed to answer the question before seeing the second video. The sequencing of videos and requirement of assessment questions needs to be made more obvious and intuitive to students. The Labs are strong overall, but this is the area that seems to allow for greatest improvement.

- Consider the limitations presented by the ability to identify and sample actual users of the NOVA Labs in the classroom. From the resources available to NOVA Education, 42 teachers were identified to participate; 27 of whom had used Labs in some form. This makes it difficult to know and generalize whether this study represents the full breadth of users. Consider strategies to better identify and know who the users are of the Labs platform to aid in better measurement of outcomes. Similarly, a larger study of the educator population may help further aid understanding of the audience.

Appendix

Table 28. Paired t-test results for student questionnaire

n=260	Pre-Mean	Post-Mean	Mean Difference	Significance
Read Graph: Cloud Height	.45	.80	.35	.000***
Open Ended: Why is it important for meteorologists to know the temperature of cloud tops	.32	.60	.28	.000***
Read Graph: Rate of Rainfall	.15	.38	.23	.000***
Open Ended: Importance for meteorologists to identify different types of clouds	.84	1.06	.22	.000***
Cloud Identification: Cumulus	.49	.66	.17	.000***
Open Ended: What meteorologists figure out from a data visualization illustrating cloud structure	.33	.49	.16	.000***
Cloud Identification: Nimbostratus	.49	.44	-.05	.202
Read Graph: Cloud Temperature	.88	.93	.05	.023
Cloud Identification: Stratocumulus	.40	.44	.04	.274
Type of Weather Associated with Cloud	.15	.14	-.01	.764
Total Correct Score	**4.5**	**5.93**	**1.43**	**.000*** **

*** Statistically significant at the .001 level