CENTER FOR RESEARCH AND EVALUATION

Lifelong Learning Group

Summative Evaluation of NOVA Labs: RNA Lab

Report of Findings

February 27, 2015

Prepared by:
Mary Ann Wojton, Ph.D.

Prepared for:
WGBH / NOVA Education

LifelongLearningGroup.org

COSI | 333 West Broad Street | Columbus, Ohio 43215

ACKNOWLEDGMENTS

The author would like to acknowledge the following individuals for their assistance with data analysis:

Deborah Wasserman
Ruoou Li

.

Executive Summary

NOVA Labs (www.pbs.org/nova/labs) is a web-based platform designed to engage teens and educators with authentic data, scientific games, tools, and opportunities to communicate with and assist working scientists. The present study sought to investigate the outcomes achieved by users of the fourth NOVA Labs platform developed: RNA Lab.

The RNA Lab includes several key components of the previous labs (e.g., videos, educator guides, etc.). The major difference is that the RNA Lab "research challenge" is a game component.

The NOVA Education team's overarching goals for teens using the Lab focused on learning content and an increased understanding that they can contribute to the larger scientific community. The goals for teachers who use the Lab are that they successfully facilitate lessons using the Labs resources, find value in including these resources in their curriculum, and demonstrate interest in further opportunities to incorporate NOVA Labs.

The RNA Lab evaluation focused on the following questions:

1. What influence does the game structure of the RNA Lab have on teen learning and engagement (including preferences, time spent, motivation, leveling-up, and out-of-school engagement)?
2. How is the use of NOVA Labs providing value to teachers' classroom practice? How do they integrate it into their curriculum/practice?
3. How does using NOVA RNA Lab impact student-learning of RNA content and awareness of STEM careers?
4. What attributes or features of NOVA Labs are most useful to teachers and instructive to students? Which are the most motivating for student learners in- and out-of-school? Do students feel they have contributed to science?
5. What attributes or features of NOVA Labs are confusing or difficult to understand (teens and teachers)?

The evaluation used multiple methods. The primary approach was identifying five teachers across the country who intended to implement RNA Lab in Fall 2014. From these test classrooms (grades 6-12), evaluators collected pre/post-test data from their 200+ student users, and conducted post-implementation interviews with the teacher-users. Supporting this study, was an effort to survey teachers known to NOVA Education as possible RNA Labs users. This survey was distributed to 82 teachers, who had expressed an earlier interest in this study, through e-mails sent from the web-based survey platform; 16 responded, six used the RNA Lab with their students.

Key Findings

Overall, this evaluation found the RNA Lab to be successful in engaging teens with the game structure of the Lab. Students were motivated by leveling up, completing puzzles and helping scientists.

Overall, the pre-post test results indicate a positive shift in student understanding of RNA Lab concepts. Students were more likely to understand RNA's function within a cell, how RNA folding works, and what RNA structure determines after completing the Lab. **Additionally, students were more aware of STEM careers after completing the RNA Lab.**

Students liked doing the RNA Lab more than usual schoolwork and were motivated to continue playing the game. This is similar to findings for the Cloud Lab, however more RNA Lab students indicated they liked the RNA Lab "a lot more than usual schoolwork" than students in the Cloud Lab study.

Teachers in this sample were able to successfully incorporate the RNA Lab into their lessons. As with prior evaluation of Sun, Energy, and Cloud Lab, teachers report the videos in the Labs are an incredible strength.

Teachers valued the Lab for providing students an opportunity to visualize an abstract science concept, provide basic RNA content knowledge in a unique format, and develop the science process skills of persistence and critical thinking. All teachers appreciated that the lab engaged the majority of their students and provided a cooperative element to learning.

Teachers are most likely to integrate the Lab into their high school level Biology and Genetics classes; middle school teachers will include it with their life science unit, specifically their cell unit. Similar to Cloud Lab findings, four out of the five teachers who were interviewed plan to use the RNA Lab with students next year.

The usability of the site continues to be incredibly strong and showed clear building upon lessons learned from the prior Labs. Students reported that the Lab was easy to use and that they were able to easily interact with the interfaces. Teens liked having two options to view the RNA structures, the "target" and "natural" views. Students were more likely to know when they were done, where to get help, and the goal of the Lab than students who participated in the Cloud Lab evaluation.

All five teachers cited examples of students working together to overcome challenges. **Teachers valued the cooperative element of RNA Lab, as it reflects how research lab work is actually completed.**

Recommendations

Based upon the findings and feedback resulting from this study, the following recommendations emerged for consideration by the NOVA Labs team as future NOVA Lab environments are developed. These recommendations are informed by the data from the RNA Lab study or are specific recommendations that were suggested by participants.

- When creating new Labs, consider including the gamification elements of leveling up and puzzles. Also consider providing students the opportunity to help a scientist. These were positively received by students in the RNA Lab study.

- As with the Cloud and Energy Lab, teachers would like additional information included in the Educator Guide. Teachers mentioned they would appreciate ideas on how to best scaffold the lab for their student's abilities and knowledge. Teachers would also appreciate a pre- and post-assessment to assess student learning, and additional information for troubleshooting technology issues.

- When developing scientific games, consider allowing teens the option to pick their skill level so they may pursue an easier or more challenging course through the game. While some teens appreciated the repetitive nature of the early levels, other found that aspect of the game boring. Skill-level might be achieved by adding questions at the end of each game level to ensure students understand the science content. This may improve the user experience and create a more robust teaching tool. Additionally, teens would like situation-specific "help".

- Reconsider the Wiki. It was underutilized in the RNA Lab. This may be because it wasn't needed or it was not discovered by users. If a Wiki is included in future Labs, consider some reorientation or improved signposting.

- Finally, consider broadening outreach to teacher users to aid in better measurement of outcomes, which would likely expand your user base. Data collection for the broader sample of teacher feedback was challenging because of the limited number of teachers identified to participate. The 82 teachers identified as possible participants had responded to the earlier RNA recruitment invitation, but since many had not taught RNA yet—since it's a spring semester topic—the number of participants for this study was low. This makes it difficult to know and generalize the results of the study to the full breadth of users.

Contents

Tables

Figures

Introduction

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, scientific games, tools, and opportunities to communicate with and assist working scientists. The NOVA Labs platform includes topic-specific labs, including RNA, Sun, Energy, and Clouds.

The focus of this report is the RNA Lab. The RNA Lab includes several key components of the previous labs (e.g.., videos, educator guides, etc.). The major difference is that the RNA Lab "research challenge" is a scientific game component which capitalizes on the potential of crowdsourcing scientific research. For the RNA Lab, NOVA Labs partnered with Adrien Trueille who created EteRNA, a realistic molecular design challenge, creating a lab which focuses on a scientific game.

To better understand how teens, both in and out-of-school, and teachers, use the RNA Lab with its various components, the Lifelong Learning Group (LLG) was engaged to direct summative evaluation of the Lab. This work will build upon LLG's prior evaluation of the Sun, Energy, and Cloud Labs. Three distinct audiences were involved in this evaluation:

- Out-of-school teens (referred to as teens throughout the report)
- In-school teens (referred to as students throughout the report)
- Middle and high school level teachers

The RNA Lab: Outcomes and Evaluation Questions

The present evaluation study sought to investigate the outcomes achieved by users of the fourth NOVA Labs platform developed—RNA Lab. The NOVA Education team's overarching goals for teens using the Lab focused on learning content and an increased understanding that they can contribute to the larger scientific community. During the scientific game, students play the role of a molecular engineer tasked to fold RNA. By solving the RNA folding puzzles, teens progress through the game. Those who complete the RNA Lab receive 5,000 points in EteRNA, where they can design RNA models that may be chosen to be tested by scientists.

The goals for teachers who use the Lab are that they successfully facilitate lessons using the Labs resources, find value in including these resources in their curriculum, and demonstrate interest in further opportunities to incorporate NOVA Labs.

The RNA Lab evaluation focused on the following questions:

1. What influence does the game structure of the RNA Lab have on teen learning and engagement (including preferences, time spent, motivation, leveling-up, and out-of-school engagement)?
2. How is the use of NOVA Labs providing value to teachers' classroom practice? How do they integrate it into their curriculum/practice?
3. How does using NOVA RNA Lab impact student-learning of RNA content and awareness of STEM careers?
4. What attributes or features of NOVA Labs are most useful to teachers and instructive to students? Which are the most motivating for student learners in- and out-of-school? Do students feel they have contributed to science?
5. What attributes or features of NOVA Labs are confusing or difficult to understand (teens and teachers)?

Methods

The evaluation used multiple methods to answer these questions. In order to assess outcomes with students and teachers who have used the Lab, teachers who were willing to incorporate the RNA Lab into their curriculum were recruited from NOVA Education contacts during the Summer and early Fall of 2014. These teachers agreed to share their experience with the Lab during a telephone interview and to collect data from their students via a pre/post-assessment. To gather data from the broader population of teachers using the RNA Lab, an invitation to complete a post-survey was sent to a list of more than 80 teachers. This list was compiled of teachers that had responded to the earlier NOVA Education RNA Lab study recruitment opportunity. Finally, to better understand teen users, a focus group of teens who had explored the RNA Lab was conducted in Fall 2014. Methods for each study are explained below, Appendix A contains all instruments.

Pre/Post Assessment of Students
A pre/post-assessment was developed to better understand students' prior knowledge of the RNA content that would be covered in the 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, specifically the scientific gaming aspect, were also included in the post-assessment. Teachers administered the pre-assessment prior to their introduction of the unit in which they would use the Lab. At the conclusion of the unit, the teachers administered the post-assessment to students. All five teachers collected data using a web-based instrument found in Appendix A. When a question appeared on only the pre- or post-assessment, all responses were used in data analysis. When a question appeared on both the pre- and post-assessment, the matched data set was used for analysis.

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

Teen Focus Group Fall 2014
In order to assess the outcomes with out-of-school teens, a focus group interview was convened with a convenience sample of science-interested teens recruited through LLG's parent institution (COSI's teen volunteer corps). Prior to attending the discussion group, teens explored the RNA Lab and at least one other NOVA Lab. During the discussion, the LLG interviewer reviewed key components of the website to understand teen's reactions to the Lab, including the gamification of the content, teens knowledge that by playing this game they were helping scientists, and any features of the Lab teens found compelling or confusing.

Post Survey of Teachers
In an effort to gather a broader sample of teacher feedback about the RNA Lab, teachers who had responded to the earlier recruitment invitation for test-classes were invited to complete an online survey. It was assumed these teachers were inclined to use the Lab in their classroom since they had responded to the earlier recruitment invitation. This survey was distributed to 82 teachers through e-mails sent from the web-based survey platform.

Timing seems to have made data collection challenging for some teachers; many of the teachers who had declined to participate as a test-class indicated RNA was not taught until spring semester.

In order to include as many teachers who had used the lab as possible, data collection for this instrument remained open until mid-February 2015. Therefore, data from that instrument are not incorporated into this report, rather they are included as an addendum.

Description of Samples

Test-Group Classrooms

Table 1 presents the characteristics of the five teachers/classes who participated in the test-group study of RNA Lab (also referred to as "interviewed teachers" throughout the report). Of the five teachers/classes that participated in this study, two were middle school teachers (grade 6 and 7)/classes and three were high school teacher/classes. Four of the teachers taught in public schools while one taught in a private school. All teachers had at least five years teaching experience, two had over 20 years of experience. Schools represented urban, suburban, and rural districts throughout the United States and its territories.

Table 1. Characteristics of test classrooms in the evaluation

Class	Grades	Course Title	School Type	Location
A	Middle School	7th Grade Life Sciences	Public	North Carolina
B	High School	Biology	Private	Puerto Rico
C	High School	Honors Genetics	Public	Pennsylvania
D	Middle School	Sixth Grade General Science	Public	Iowa
E	High School	Biotechnology	Public	Texas

More than 200 students completed the pre- and post-tests in the five different schools. Matched pre- and post-test data were obtained from 177 students. Table 2 breaks down testing numbers by school.

Table 2. Student testing totals

Class	Total Pre-Test	Total Post-Test	Total Matched
A	129	117	86
B	31	21	19
C	50	45	42
D	17	17	14
E	17	16	16
Total	**244**	**216**	**177**

Teachers/students accessed the RNA lab on tablets, laptops, and computers (see Appendix B for a breakdown of technology use by class). All students were able to access the lab individually, which was not the case with previous labs. Challenges with the technology were limited, with students and teachers working together to help struggling students. Two teachers reported challenges with Wi-Fi, one of whom solved the issue by connecting to wired internet.

Teen Focus Group

The ten teens who participated in the focus group represented a variety of races/ethnicities, socio-economic situations, and grades. Students were from impoverished urban schools and affluent suburban schools. Two teens were in middle school and seven were in high school; half of the teens were ninth graders. See Table 3 for participants' grade levels.

Table 3. Focus group participants' grade levels

Grade Level	Number of Focus Group Participants
7	1
8	1
9	5
10	2
11	1

Findings

Question 1. What influence does the game structure of the RNA Lab have on teen learning and engagement (including preferences, time spent, motivation, leveling-up, and out-of-school engagement)?

What We Know

Students explored the RNA Lab thoroughly and responded positively to it. The majority of students and teens participating in this study self-reported completing the Tutorial and Level one; approximately half of the students and teens completed Level 2. The majority of students who started a level were likely to successfully complete it.

Students liked doing the RNA Lab more than usual schoolwork and were motivated to continue playing the game. These students and teens reported the lab was fun, educational and engaging. They spent time playing the Lab game because they enjoy solving puzzles, leveling up, learning about RNA, helping scientists, and competing with their classmates.

Students who were motivated to level up, complete puzzles and help scientists were more likely to have a positive change in number of correct responses pre- to post-assessment. This was also true for students who watched the videos.

How We Know

This section begins by presenting student and teen engagement data, followed by deeper examination of how students and teens engaged with the Lab, especially the gaming aspects. Finally, the data were examined for connections between engagement and learning.

All teachers assigned the Tutorial and Level 1, however a small percentage of students responding to the post-assessment indicated they did not complete these levels. The results are shared in Table 4. These students may have misunderstood the question (checking the box of the highest level completed), missed school during Lab work, or were uninterested.

Table 4. Student engagement with the RNA Lab

Level	% of Students Engaged
Tutorial: The Basics	87%
1: Protein Synthesis	79%
2: RNA World	49%
3: Virus Attack	15%

Students who engaged with the Lab were successful (somewhat or mostly) at completing levels they attempted. Although the percentage of students who attempted a level decreased for each level beyond the Tutorial, the percentage of students who reported they were mostly to totally successful completing a level consistently remained around 60%.

Teens who participated in the focus group were not big gamers; two thirds shared that they typically do not play video games in their free time, and half (5 out of 10) spend five hours or fewer a week playing video games. The length of time teens engaged with the RNA Lab prior to the focus group varied from ten minutes to more than 60 minutes. All of the teens completed the Tutorial and began Level 1, and one completed the entire game. Table 5 illustrates teen engagement with the RNA Lab.

Table 5. Teen engagement with the RNA Lab

Level	Number of Teens Engaged
Tutorial: The Basics	10
1: Protein Synthesis	10
2: RNA World	6
3: Virus Attack	1

Both students and teens were provided opportunities to share their feelings about the RNA Lab; students completed the post-assessment and teens commented verbally during the focus group. The following part of the report begins by examining student and teen comments regarding the RNA Lab, followed by student and teen comments regarding video games in general. Additionally, teacher comments were included to support student findings.

RNA Lab (Students)

In the post-assessment, students were provided several opportunities to share their feelings about the RNA Lab components, including the videos, wiki, and scientific game component. Post-assessment questions that provided this opportunity included the following:

- Comparing the RNA Lab to their regular coursework and explaining why they gave that rating
- Sharing what motived them to keep playing the game, if they found the game motivating
- Sharing what would motivate them to play the scientific game outside of class
- Sharing their favorite part of the Lab

Several themes emerged from student answers to these questions.

RNA Lab compared to regular coursework. The majority of students (62% or 137/220) indicated that they liked doing the RNA Lab more than usual schoolwork. See Figure 1. While this

is similar to the 60% of students who reported they liked doing the Cloud Lab more than usual schoolwork, it is important to point out that more RNA Lab students liked the Lab "a lot more" than Cloud Lab students (39% RNA Lab to 22% Cloud Lab) These students also indicated the Lab was fun (63% or 86/137) and educational (42% or 57/137). Students completing the assessment shared the Lab "*was an interesting twist to a regular topic"* and it *"tested your mind in a way that school work doesn't."*

Additionally, 22% (30/137) of students believed the game was engaging. One student wrote, "*It was a very fun and engaging game which also gave me a reason to want to do well and advance*" Another student shared, *"It is an engaging activity that encourages ingenuity and innovation all while reinforcing my RNA knowledge."*

The 18% (40/220) of students who liked the usual school work better than the RNA Lab reported they gave it that rating because they felt the Lab was boring (63% or 25/40) or confusing (42% or 17/40). A student who felt it was confusing shared, *"It was a little bit difficult to learn very much because it was confusing at times. The instructions of the game could have been better explained. You should also have an easy-moderate-difficult setting and give video examples with narrations explaining what you need to do. You might want to consider making this game a little more interesting, as it did get a little boring after a while."*

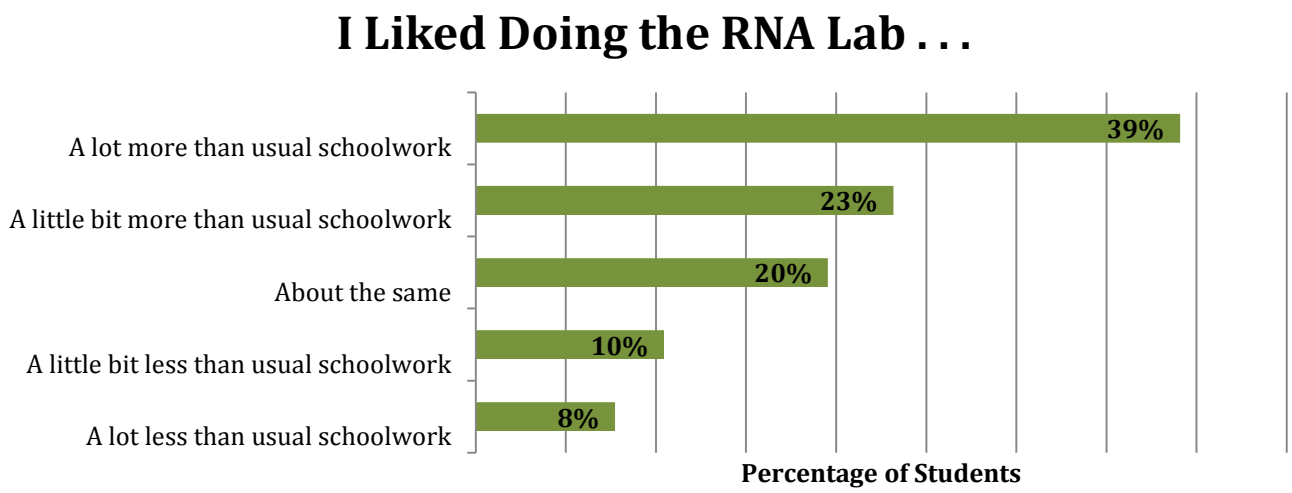

Figure 1. Student comparison of RNA Lab to schoolwork (n=220)

Motivation to play the game. Students were asked to indicate how motivated they were to continue playing the RNA Lab game. The majority of the students (92% or 195/213) indicated they were motivated to continue playing the game by choosing "A Little" (21% or 45/213), "Some" (34% or 72/213) or "A Lot"(36% or 76/213). Only 9% (20/213) of students were "Not At All" motivated to continue playing the RNA Lab game.

The 195 students who indicated they were motivated to continue playing the game saw a follow up question asking them to indicate which of five different gaming elements might have motivated them (they were able to choose more than one). Students indicated that they were most motivated by solving puzzles, getting to the next level, and helping scientists. See Table 6.

Table 6. Student game playing motivators

Motivator	% of Students
Solving puzzles	74% (145)
Getting to the next trial of the game	65% (127)
Helping scientists do their research	45% (88)
Learning about RNA	41% (80)
Unlocking videos	16% (32)

N=195

Playing the game out of class. Similarly to the findings of the Cloud Lab study, half of the students (108/216) report they would use RNA Lab, or another NOVA Lab, for a future school project, and 30% (65/216) would tell a friend. More RNA Lab students, 48% (103/216) would continue exploring the Lab even though the assignment is complete, than Cloud Lab students (34%). One third of the students (72/215) would share the RNA Lab on Social Media.

Additionally, 20% (61/218) of the students indicated they continued playing the RNA game out of class. Almost half of these students would continue playing because they believed the game was fun (41% or 25/61). Additionally, the students shared they would continue playing because they wanted to move to the next level (15% or 9/61) and help scientists (8% or 5/61).

Student favorite Lab elements. Of the 204 students who responded to an open-ended question asking students to list their favorite part of the RNA Lab, the following student answers were shared by 10% or more of the respondents. When asked why this was their favorite part, students said that the Lab was fun, challenging, or cool, helped them learn, or provided them with a sense of achievement.

Table 7. Student-reported favorite elements

Favorite	% of Students
Solving Puzzles	22%
Playing a Game	18%
Completing the Game	13%
Learning about RNA	12%
Helping a Scientist	10%

N=204

The five teachers interviewed supported student reported themes of the Lab being fun, the importance of solving puzzles, and leveling up. Three of the five teachers believed that solving the puzzles was the most important aspect of the Lab for their students. One high school teacher believed his students completed each RNA strand to *"see the next one."* In general, teachers shared they believed the students enjoyed the game because:

- They like solving puzzles
- They are competitive, they wanted to beat their classmates or obtain a high score
- They liked the graphics and sound effects

Two interviewed teachers surveyed students to determine how they felt about the Lab. Middle school students found the lab fun (rating it an average of 3.7 on a 5 point scale) and 59% (13/22) found it more helpful than regular schoolwork. They indicated that they were motivated to continue playing the game because they wanted to get to the next level, and they liked the videos and puzzles best. All of the high school students surveyed found the Lab more helpful than regular schoolwork (13/13). Like the middle school students, they were motivated to continue playing the game by the opportunity to level up.

RNA Lab (Teens)

Teens in the focus group shared they were motived by the bubbles and lights that appear after correctly folding the RNA when you complete a segment, and the faster pace and intellectual challenges provided by higher levels. One focus group teen shared, *"the [RNA Lab] kept me engaged for 30 minutes, sometimes I lose interest in two seconds. There are so many [game] choices out there."*

The teen who completed the game liked the challenge provided by the *"energy field."* She examined the site map and realized the final levels were complicated, and she *"wanted to see if [she] could complete the harder levels."* She felt the game was easy until the "Virus Wars" Level. Her comments about level three motivated the other teens in the focus group to return to the game to play level three, the Virus Attack.

The majority of teens (8/10) believed playing the game was contributing to the larger scientific community. One teen shared that he was motivated to complete the game because *"researchers in California are trying to solve for major diseases, and this could actually have an impact. Scientists could use your data."* The teen who completed the entire game did so because she wanted the 5000 points that carry over to EteRNA. She expressed a desire to have a scientist test one of her RNA structures.

Video Games (Students)

In the pre-assessment, students were asked to rate elements of computer games (not specific to the RNA Lab scientific game), on a scale of 1 (Not Necessary) to 5 (Essential). All components scored above the midpoint (2.5 on a 5 point scale; see Table 7). The top three student rated components were unlocking different levels (4.1), customizable features (3.7), and accumulating points (3.6).

Table 8. Rating of Elements of Computer Games

Component	Mean Score
Unlocking different levels	4.1
Customizable features	3.7
Accumulating points	3.6
Game recognizes my login or player character	3.5
Competing with others	3.4
Able to see high scores on a leaderboard	3.4
Winning badges	3.1
Hints from non-player characters	2.6

N varies from 242-245

Video Games (Teens)

During the focus group, teens were asked what motived them to play video games, in general. Shared game elements that motived them include:

- Competition (e.g., beating an opponent or getting a faster time)
- Learning something (jGuru, pre Text to Java, a feel for coding)
- Reward (badges, coins, etc.)
- Solving puzzles
- Unlocking new levels

Four of ten teens mentioned they liked combat games, explaining that they are motivated when there is an enemy or time limit. Three liked games with puzzles, especially the "Professor Layton" series. One shared that she likes to learn from the games she plays. Other teens shared they like to "get points," as well as "awards" and "coins."

Social Media (Students)

The majority of students (67%) indicated they would not share the RNA Lab on social media with their friends. Students gave the following reasons for not sharing the RNA Lab game on social media:

- Believed friends weren't interested
- Don't do social media
- Don't share games on social media
- Thought the game was too much like school

This echoes findings from the Sun Lab evaluation.

Engagement and Learning

Students motivated by the factors below were more likely to see a statistically significant increase in the proportion of correct answers pre to post-assessment, as verified by a Mann-Whitney test. A Mann-Whitney test was used with the non-parametric data (power with sample size of 177, power to detect a difference with .95 confidence >.99).

- Level Up ($Z=-2.760$, $p<.010$)
- Complete puzzles ($Z=-2.104$, $p<.050$)
- Help scientists ($Z=-2.520$, p. $<.050$)

Question 2. How is the use of NOVA Labs providing value to teachers' classroom practice? How do they integrate it into their curriculum/practice?

What We Know

Teachers valued the lab for providing students an opportunity to visualize an abstract science concept, provide basic RNA content knowledge in a unique format, and develop the science process skills of persistence and critical thinking. All teachers appreciated that the lab engaged the majority of their students and provided a cooperative element to learning. High school teachers integrated the lab into Biology, Genetics, and Biotech classes; middle school teachers included it with their life

science unit. The high school teachers and one middle school teacher will likely use the RNA Lab again.

How We Know

Findings in this section are derived from semi-structured interviews with the five test-group teachers following their implementation of the Lab.

Integration

High school teachers planned to use the RNA Lab with their Biology, Honors Genetics, and Biotechnology students. To accommodate this evaluation, four of the teachers taught the RNA Lab out of context with the curriculum, the fifth added it to her middle school general science curriculum as an enrichment. This year a high school biology teacher connected the RNA Lab to his nucleotides and nitrogen bases unit; next year he will include it with his molecular biology unit. This year a middle school teacher connected it to his introductory unit on the human body, next year he will connect it to his unit on cells. The preferred units are taught in the second (Spring) semester.

Middle and high school students in this study were given time to complete the RNA Lab during at least three class periods, for approximately 45 minutes each period. All students worked individually, at their own pace, watching the videos and completing the game levels. All interviewed teachers directed their students to complete the following elements of the RNA Lab:

- RNA Enigma and Protein Synthesis Cellular Factory Videos
- The Basics and Trial 1: Protein Synthesis

Only one teacher assigned levels of the RNA Lab beyond Trial 1. All interviewed teachers believed they had students who worked beyond Trial 1. One teacher believed 25% of her students completed the entire game because the students wanted the points to begin the EteRNA game. Three interviewed teachers mentioned they knew of students who played the game on their free time.

Engagement

As with prior labs, teachers were positive about the professional quality of the Lab and its potential to engage students, align with science standards, and meet their curricular needs. One high school teacher mentioned the challenge of finding educational websites like RNA Lab that were appropriate for high school students, as many websites are geared at higher or lower grade levels. One high school teacher liked RNA Lab so much she shared it with other life science teachers at a statewide conference she attended.

One teacher shared that a benefit of the game was that it took students out of their normal routine. Another reported her students enjoyed the game aspect so much that some of her students were *"looking forward to class so they could play the game."* Teachers suggested that students who were not engaged were *"not into video games"* or *"overwhelmed,"* most likely because they had little prior knowledge of RNA concepts.

Teachers also believed the RNA Lab was a *"good hook"* for students who are *"borderline motivational"*, e.g. students who don't tend to participate in traditional classes. A high school teacher said his students thought the RNA Lab *"is pretty cool."* One teacher shared that one of his

students commented, *"I should be a scientist."* Completing the game in stages kept his students engaged. Some of his students saw it as a competition, but all his students had fun.

Visualization and Interactivity

The three high school teachers voiced appreciation for the RNA Lab's ability to help their students grasp a concept that is difficult to visualize. These teachers used the RNA Lab as an introduction to or a review of RNA and protein synthesis. One high school teacher had lectured students about proteins and the importance of their 3-D structure, but the RNA Lab clarified this by providing visuals. He believed the Lab helped his students understand that RNA molecules have *"a shape and they need a particular shape to function."* An additional element the teachers valued was the interactive elements of the RNA Lab. One high school teacher believed this interactivity was *"very effective"* at showing students how the matches create the shapes.

Content in a different way

Teachers valued the Lab for its ability to teach students RNA content differently than a textbook. While one high school teacher shared that the Lab provided students with *"the basics of RNA, base pairing, understanding that RNA folds into specific shapes and that each shape is associated with a function."* Another shared that the Lab helped his students understand that molecules do have a shape, and that they are not flat: *"They can't imagine the molecule because it is so small and it has so many responsibilities, and it's so important to maintaining life."* The game *"gave them the feeling that they had to fix things so the RNA would fold properly,"* which they do not get from a textbook.

Science Process Skills

Both middle school teachers believed the Lab helped their students develop science process skills. One believed the Lab helped her students with the scientific process skill of persistence, teaching the students *"that is it OK to fail, as long as they keep trying."* One high school teacher believed the RNA lab helped her students develop critical thinking skills. She appreciated the challenging level of the labs, because *"that is real life."*

Cooperative Element

Unlike prior labs where activities needed additional directions or scaffolding, teachers believed this platform was relatively easy for many students, all five teachers cited examples of students helping each other overcome challenges. This cooperative element was valued by teachers because it reflects how research lab work is actually completed. A high school teacher believes the Lab opened his students to the future job possibilities of working in RNA research, as much of that work is cooperative. A middle school teacher believes that the Lab was laying the foundation for his students "to become the scientists of the future."

Question 3. How does using NOVA RNA Lab impact student-learning of RNA content and awareness of STEM careers?

What We Know

Overall, the pre-post test results indicate a positive shift in student understanding of RNA Lab concepts. Students were more likely to understand RNA's function within a cell, how RNA folding works, and what RNA structure determines after completing the Lab. Additionally, students were more aware of STEM careers after completing the RNA Lab.

How We Know

Content (Students)

Overall, the pre-post test results indicate a positive shift in student understanding of RNA Lab concepts. The pre- and post-assessment for content knowledge consisted of four multiple choice questions and two open-ended questions. The multiple choice questions were worth one point each, the open-ended questions were each worth two points, for a total of eight points.

Matched data indicate a statistically significant increase pre-post assessment, verified by a t-test (t=9.712, p<.001). The average student score (matched data) on the pre-assessment was 2.29 and the average score on the post-assessment was 3.55; an increase of 1.26 points was seen pre to post-assessment. Both pre- and post-assessment scores were below the midpoint for the 8 point assessment.

Tables 9 and 10 list each of the knowledge questions on the pre- and post-test, the percent who answered the question correctly, and the change between the pre- and post-test.

Table 9.Comparison of pre- and post-test results for student questionnaire (for 1-point multiple-choice questions)

	% of Sample Answered Correctly		
Question Topic	**Pre**	**Post**	**Change**
RNA's function within a cell	45%	73%	⬆28%
RNA structure=function	42%	65%	⬆23%
RNA order of assembly	36%	46%	⬆10%
RNA bases that bond together	41%	48%	⬆7%

N=177 Pre and Post (Matched Data)

Table 10. Comparison of pre- and post-test results for student questionnaire (for 2-point short response questions)

	% of Sample Answered Correctly		
Question Topic	**Pre**	**Post**	**Change**
RNA folding	7%	35%	⬆28%
RNA versatility	9%	25%	⬆16%

N=177 Pre and Post (Matched Data)

Figure 2 illustrates the increase in students' total correct number of responses from pre- to post-test; the blue (pre-test) and green (post-test) bars each form a normal distribution, with the mode score at 2 of 8 in pre, and 3 of 8 in post. The highest grade a student received on the assessment was 7 out of 8.

A Wilcoxan signed-rank test was used to determine statistical significance for individual questions (power with sample size of 177, power to detect a difference with .95 confidence >.99).
The Wilcoxon signed rank sum test is the non-parametric version of a paired samples t-test. Pre- and post-test data for paired students found statistically significant positive gains for four of the six items:

- RNA's function within a cell (Z=*-5.417*, p<.001).

- RNA structure = function (Z=--3.395, p<.001).
- RNA folding (Z= -7.413, p<.001).
- RNA versatility (Z= -5.815, p<.001).

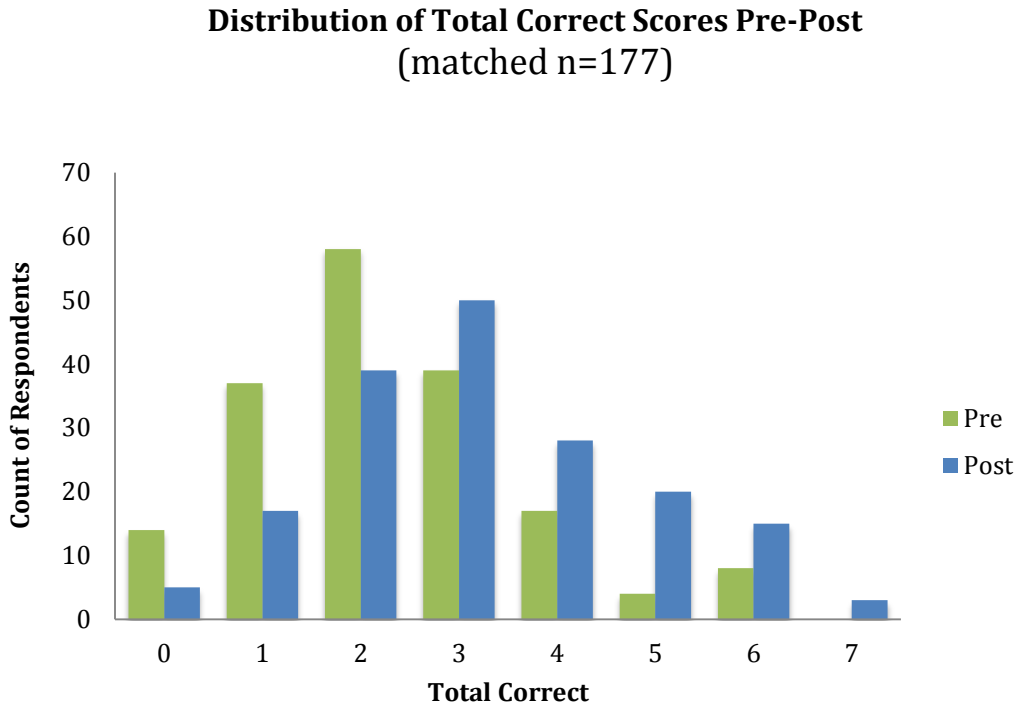

Figure 2. Distribution of total correct scores pre and post-Lab

Content (Teens)

Middle school level teens who participated in the focus group appeared to learn the most science content from the RNA Lab. For example, an eighth grade teen was completely unfamiliar with RNA before exploring the RNA Lab, and a seventh grade teen learned RNA was "connected to" DNA. High school level teens either had taken Biology or were taking Biology, so they were more familiar with RNA. One ninth grader taking Biology reported that he "knew a lot about bonds, but boosts were new." Another high school teen shared that his Biology teacher had recently given the class a worksheet to complete about RNA. He felt the RNA Lab "captured [RNA] more in depth" than the worksheet, and he felt it was easier to understand. One of the teens appreciated the animation that showed what RNA does, that it does "more than transfer information from DNA to ribosomes, showed RNA synthesis." He believed that point was built upon in the different gaming levels.

Regarding the education value of the website, the focus group teens had different opinions, most likely based on their prior knowledge of RNA. The middle school and ninth grade students taking Biology felt they learned something about RNA from the RNA Lab while those who had taken AP Biology wanted more specific information about RNA. One AP student shared, "getting through the labs doesn't really involve learning about RNA, it was about following instructions, C goes with G, then you click on it, then you drag." She would have liked more information about hydrogen bonding and more specifics about RNA.

Awareness of STEM Careers (Students)

Significant changes were found among students who completed both pre and post test data about their assisting working in a science related career center. While the majority of students (92) saw no change, 58 of 174 students were more interested in working in a science-related career post-assessment. (Z= -3.644, p<.001).

Teens who complete the RNA Lab and move onto EteRNA will be participating in scientific research. The creators of EteRNA found that humans are better than computers at predicting the patterns that guide RNA folding. EteRNA players vote for their favorite player-created RNA designs. Winning designs are created in the laboratory. After completing the Lab, almost half of the students (47%) were aware of participating in a scientific research study. Additionally, 64% of the students understood that playing the scientific game in the RNA Lab helped scientists.

Question 4. What attributes or features of NOVA Labs are most useful to teachers and instructive to students? Which are the most motivating for student learners in- and out-of-school? Do students feel they have contributed to science?

What We Know

All five interviewed teachers were successfully able to deploy the RNA Lab, including videos and the scientific game. These teachers, as well as teachers in prior studies, found the videos to be a strength of the Lab. The majority of students and teens enjoyed the videos and completed the Tutorial and Level 1. Almost half of the students completed Level 2. Students reported they understood the goal of the website and where to get help. The RNA Wiki may be an underutilized part of the website, as very few students (7%) and none of the focus group teens used it.

How We Know

Useful Attributes (Teachers)

As with prior Labs, teachers continued to consider the videos to be a strength of the Lab. While all five teachers appreciated that the videos were short and succinct, and felt that they were high quality compared to other websites, one teacher expressed a concern about the videos "cartoonish" nature. Middle school teachers especially appreciated the videos because they provided students with concrete examples of abstract concepts. One middle school teacher shared that *"It helped [the students] visualize the RNA Processes . . . these are better than my drawings."* One high school teacher appreciated the analogy of comparing protein synthesis to a machine, which was the message of a video. Additionally, teachers appreciated the quiz after each video to ensure student understanding.

High school teachers believed the content level was appropriate, while middle school teachers thought the content was challenging for their students. Both middle and high school teachers believed their students found the content challenging because they lacked prior knowledge of the concept. High school teachers whose students already had biology were more likely to believe their students found the Lab easy, while middle school teachers whose students had minimal life sciences background reported that their students found the Lab more challenging

Three of the five interviewed teachers shared that they used the Educator Guide. These teachers used the Educator Guide for background information and reported gaining a better understanding of the RNA Lab from the materials provided.

Useful Attributes (Students)

The majority of students self-reported the RNA Lab was easy to use and they were able to easily interact with the interfaces. Students were most likely to report that it was easy to know when they were done (72%), where to get help (63%), and what the goal was (61%).

The majority of students (55%) found the VirtuaBot helpful. The RNA Wiki may be a hidden asset of the website; only 7% of students completing the post-assessment indicated they used the RNA Wiki.

Useful Attributes (Teens)

Overall the majority of the teens liked the site, with focus group participants describing it as a *"fluid webpage," "visually appealing"* and *"easy to navigate."* As one teen shared, *"[It] gave you step by step directions [and] guided you through the process."* Most logged in with a guest pass, although the one who finished the game set up an account.

Teens liked the videos and expressed appreciation that they were animated; as one teen put it, *"cartoons are cuter than the real life thing."* They liked that the videos were short and visually appealing. Half of the teens used the Virtuabot and thought it was helpful. Of the teens who used the Virtuabot, one indicated *"I thought it was helpful when it showed me how to move the background, I feel it helped with the background, how to click help, I could use QWE, and quickly drag the bonds I made."* Another shared that she would have liked to minimize the Virtuabot once she had a basic understanding of the game. None of these teens used the Wiki. When asked why, several stated they had not seen the Wiki.

Another aspect of the website that the teens liked was having two options to view the RNA structures, what they called the "target view" and the "natural" or "leaf" view. They liked being able to "click on the leaf" to see *"what it would actually be folding like."* Several teens felt the RNA Lab was *"easy and straight forward, especially when . . . it is in 'target' mode instead of 'natural' mode."*

Question 5. What attributes or features of NOVA Labs are confusing or difficult to understand (teens and teachers)?

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.

What We Know

While the majority of teachers and teens considered the videos to be a strength, respondents from both groups suggested incorporating real images to the videos. Teachers would like the addition of questions between game levels to ensure students understand the content. Teachers also suggested several possible additions to the Educator Guide. Teens would like additional levels and an option to level up if they believe they have mastered a level.

How We Know

Teachers

Teachers who reported challenges with platform usability tended to have difficulty with the Wi-Fi at their school or the hardware, including new hardware that was unfamiliar or hardware that was not updated with the latest version of Adobe Flash. One high school class had a difficult time downloading the videos; however, this was most likely due to the school's Wi-Fi. When the teacher switched his students to a wired system they were able to download and watch the videos.

One teacher, who was using new Surface tablets, found the Lab to be *"touchscreen unfriendly."* She shared that in Trial 1, her students were unable to drag a triangle into a white circle with the touch screen. She fixed this by having her students connect keyboards to the tablet. Another teacher, whose students had a challenge correctly typing in the URL for the Lab, suggested creating a QR code for the URL.

Although the majority of teachers viewed the videos as a strength of the Lab, one high school teacher shared that his students felt the videos were geared for middle school level students because they were *"cartoonish,"* even though the *"content was at their level."* This teacher suggested using real images.

Although high school teachers felt the content was appropriate for their students, middle school teachers felt the Lab content was challenging for their students. One middle school teacher felt the vocabulary was advanced for her students and that the game required a lot of focus for the typical middle school student. The other middle school teacher believed his students found the Lab challenging because they expect the answer to *"leap up to them"* and if it does not, they believe *"it is impossible."* Two high school teachers believed their students found the content challenging because this was their first introduction to molecular folding or protein synthesis.

To ensure understanding of each level's key concept, teachers would like students to be asked content-based questions between levels. One middle school teacher wished the game was able to recognize a student's incorrect patterns and offer more detailed hints to help the student.

Teachers would like the following elements added to the Educator Guide:

- A pre- and post-assessment they could use to assess student learning.
- A "cheat sheet" that explains how the game works, so teachers with little technology knowledge can explain the Lab to students
- Ideas for appropriate scaffolding so they can help their students better understand the concepts
- A list of Frequently Asked Questions about technology fixes
- Vocabulary List

Students

While the majority of students felt the RNA Lab was fine as it is (78/215), 33 students suggested modifying the instructions for easier understanding including:

- *"Make the instructions clearer when you are making proteins"*
- *"Use more arrows"*

- *"Maybe add a voiceover at the beginning of the trial explaining what the purpose is/what is being learned in that trial"*
- *"Give hints on what to fold"*

Students would also live additional levels (13) and more information (11) about RNA and what it does. Seven high school students suggested making it more challenging while six middle school students suggested making it easier. One high school student shared, "*Once thing you can do is have a more fast paced option for students who already have background in RNA or for students who pick up on it easily. I think a huge part of the reason why my classmates didn't like it is because they got bored."* A middle school student shared, "*give more hints or help because some of the game was hard."*

Teens

Focus group teens expressed an interest in seeing additional videos, suggesting possibilities like *"a time lapse [animation], maybe of a cell dividing,"* and *"microscopic images of RNA, from an electron microscope."*

One teen expressed a desire for more screen control and specifically mentioned a challenge with images on the screen zooming in and out, *"without you really wanting it to."*

Regarding the directions, one teen suggested including a short video, *"a kind of tutorial, instead of the Virtuabot telling you what to do, a little video of someone actually doing it."* This was met with some resistance because other teens did not want to lose the puzzle solving aspect of the Lab. Another teen suggested *"a video at the beginning of each trial . . . that tells you what is going on and you can see people playing the game. You see people doing it for one strand of RNA."* Everyone agreed a video would be best as an introduction option because it was important to maintain the puzzle solving aspect of the RNA Lab.

When one teen mentioned she felt the game was repetitive during the discussion group, several others shared similar feelings that the game was a little slow at the beginning due to its repetitive nature (e.g., *"when I was connecting the chains it was repetitive"*). These teens wanted additional levels of difficulty, possibly three to four beyond the "natural" mode. Another suggested having the option to pick your skill level (i.e., beginner, intermediate, advanced) in order to pursue a more challenging course through the game. The teen who completed the game wished she could have skipped forward to the next level once she demonstrated mastery of a level. These teens would have liked to receive points for completing a level and to use those points to *"buy videos, additional levels, or harder skill levels, i.e. once you get 100 points you can go to the next level of hardness."*

Teens also mentioned the need for additional supports—when they got stuck, they tended to give up. For example, one teen got stuck in Level 2, where some numbers of the RNA structure were overlapping. She shared, *"I thought I did it but it wasn't working and I couldn't figure out what I was doing wrong."* She felt the "help" she received was too general, and that she needed something more specific in order to continue.

Finally, those who had already taken Biology in school would have liked additional specifics about RNA in order to learn more. Suggestions for additional information include the following:

- Foundational organic chemistry for those who have not taken that class
- Additional examples of RNA form and function

- Additional information about different protein groups, including Helix and Beta shaped proteins

Conclusions & Recommendations

Overall, this evaluation found the RNA Lab to be successful in engaging teens with the scientific game structure of the Lab. Students who were motivated to level up, complete puzzles and help scientists were more likely to increase their understanding of RNA science content knowledge. This was also true for students who watched the videos. Students were more likely to understand RNA's function within a cell, how RNA folding works, and what RNA structure determines after completing the Lab. Additionally, students were more aware of STEM careers after completing the RNA Lab.

Similar to Cloud Lab findings, four out of the five teachers who were interviewed plan to use the RNA Lab with students next year. Teachers valued the Lab for helping students visualize a difficult concept, develop science process skills, and foster student cooperation. Additionally, teachers appreciated that the Lab engaged their students with the content differently than a traditional text book.

All five teachers were successfully able to deploy the RNA Lab, which is an improvement from the Cloud Lab. As with past Labs, teachers found the videos to be a strength of the Lab. The teachers introduced the Lab and then allowed the students to work at their own pace, which is different from the Cloud Lab findings due to the lack of computers available for student use. In classes where students needed additional support, teachers encouraged students to help each other. This cooperative element was valued by teachers because it reflects how research lab work is actually completed

The usability of the site continues to be incredibly strong and showed clear building upon lessons learned from the prior Labs. Students reported that the Lab was easy to use and that they were able to easily interact with the interfaces. Teens liked having two options to view the RNA structures, the "target" and "natural" views. Students were more likely to know when they were done, where to get help, and the goal of the Lab than students who participated in the Cloud Lab evaluation. The RNA Wiki was underutilized by teens and students, this new element of the Labs may need better signposting in order for users to discover it.

To contextualize these results, it is worth noting that this study involved a relatively small sample of teachers and students used the RNA 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 full breadth of NOVA Labs usage in classrooms, as it was difficult to obtain a statistically meaningful sample of teachers for the post-survey of teachers. An increased ability by NOVA Education to identify the number of users of Labs may be valuable in future study or documentation of impacts due to this rich set of resources for teachers and students. This echoes the findings of the Cloud study.

Recommendations

Based upon the findings and feedback resulting from this study, a few recommendations emerged for consideration by the NOVA Labs team as you develop future NOVA Lab environments. These

recommendations are informed by the data from the RNA Lab study or are specific recommendations that were suggested by participants.

- When creating new Labs, consider including the gamification elements of leveling up and puzzles. Also consider providing students the opportunity to help a scientist. These were positively received by students in the RNA Lab study.

- As with the Cloud and Energy Lab, teachers would like additional information included in the Educator Guide. Teachers mentioned they would appreciate ideas on how to best scaffold the lab for their student's abilities and knowledge. Teachers would also appreciate a pre- and post-assessment to assess student learning, and additional information to troubleshoot technology issues.

- When developing scientific games, consider allowing teens the option to pick their skill level so they may pursue an easier or more challenging course through the game. While some teens appreciated the repetitive nature of the early levels, other found that aspect of the game boring. Skill level might be achieved by adding questions at the end of each game level to ensure students understand the science content. Additionally, teens would like situation specific "help".

- Consider additional study to better understand student learning of key RNA concepts included in the RNA Lab. While there was a statistically significant increase pre-post assessment, the average student score on both assessments was below the midpoint on the 8 point assessment.

- To ensure students understand the concept of the game level, consider adding questions in between levels. If possible, provide advanced students the option to answer these questions to advance to the next level without completing a level.

- Consider a mix of real images and animation when creating videos for teen audiences. Teens suggested microscopic images of RNA from an electron microscope or time lapse video of a cell dividing.

- As with the Energy Lab, teens would like situation-specific "help". While the majority of students found the VirtuaBot helpful, both students and teens cited examples where they found the help received from the VirtuaBot too general to solve their issue.

- Reconsider the need to include a Wiki. It was underutilized in the RNA Lab. This may be because it wasn't needed or it was not discovered by users. If a Wiki is included in future Labs, consider some reorientation or improved signposting.

- Consider the curriculum when creating report deadlines. RNA is traditionally taught in the spring semester. Test-group teachers who participated in this study adapted their curriculum in order to participate. Incorporating the Lab in the regular curriculum might provide additional information of Lab use for high-stakes testing content.

- Finally, consider broadening outreach to teacher users to aid in better measurement of outcomes, which would likely expand your user base. Data collection for the broader sample of teacher feedback was challenging because of the limited number of teachers

identified to participate. The 82 teachers identified as possible participants had responded to the earlier RNA recruitment invitation, but since many had not taught RNA yet—since it's a spring semester topic—the number of participants for this study was low. This makes it difficult to know and generalize the results of the study to the full breadth of users.

Appendix A: Information Sheets and Instruments

Education Resource Study
Information Sheet for Parents & Students

September 2014

Your teacher will be using some new educational lesson plans and materials during a part of this year's study of the natural world. These resources have been created by a non-profit organization that would like to know how well they work in real classrooms. To do this, we are getting feedback from some students who use the resources this year.

What you (the student) will do:
Before and after the teacher does these lessons with the class, the students will answer a brief set of questions on a paper form or online questionnaire (about 10-15 minutes) about what they know about the topic and what they thought about the activities in class. All students will participate in the classroom lessons as part of the normal school-day, but participation in the pre/post questions is completely voluntary. You or the student has the opportunity to not participate in the study portion or to skip questions without negative consequences.

Potential Risks & Confidentiality:
There are no known risks to participating in this study. No personally identifying information will be asked of students, and only the teacher will know the student's identity, which will protect confidentiality. Your teacher may request to keep a copy of their students' individual responses about the unit and to use that information in their ongoing assessment of each student's progress. All data will be stored in a secure, locked cabinet or electronic storage in the researchers' office.

Benefits:
There will be educational benefits from the units led by your teacher, there are no other tangible incentives for participating in the study of the lessons' effectiveness. Additionally the study will help the curriculum developers improve the resources it provides in the future.

If you have questions:
Below is contact information for the evaluators leading this study. Please contact us at any time with any questions you may have about the study.

If you have any questions about the study that you can't discuss with the evaluator, you may call the institutional review board over this study: E&I Review, phone: 816-421-0008.

To opt-out of participation:
If you (student or parent) do not want to participate in the study (completing the brief questionnaires), please contact the evaluator (info below) and/or tell your child's teacher.

Sincerely,

Project Evaluators
Jessica Sickler & Mary Ann Wojton
Lifelong Learning Group
jsickler@cosi.org & mwojton@cosi.org
614-629-3148

Education Resource Study
Information Sheet for Students

September 2014

Dear Student,

Your classroom will be testing some new classroom materials during your class's upcoming study of RNA. The materials were developed by a leading science education media company, and we want to understand how well they work for middle and high school students. We are getting feedback from some students who use the resources this year, and would like to include your feedback.

What will you do:
Your teacher will ask you to complete a brief form (either paper or online) with questions related to the materials. You'll complete one before and one after you study this unit. Completing these forms is your decision. You can decide to not participate or to skip questions.

Potential Risks & Confidentiality:
There are no risks to you by completing these forms. No personally identifying information (like, your full name or date of birth) will be asked. Only your teacher will know who is and isn't included. Your teacher may request to keep a copy of your answers to better understand what you learned from this unit. All forms we receive will be stored securely.

Benefits:
Although there are educational benefits to your classwork, there are no direct benefits for participation in the study. The study will help us improve the materials we create for future teachers and students.

If you have questions about this study:
Below is contact information for the person leading this study. You may contact us at any time with any questions you have about the study. You can also talk to your teacher or parent/guardian with
any questions.

If you don't want to participate in this study:
If you decide at any time that you don't want to participate in this study by completing the forms, you can tell your teacher or contact the evaluator (below).

Sincerely,

Project Evaluator
Mary Ann Wojton
Research Associate
Lifelong Learning
Group
mwojton@cosi.org
614.629.3148

Student PRE-Assessment RNA Lab

Highlighted statements represent correct answers

Your classroom is testing some new materials during your class study of RNA. We want to understand how well they work for students and teachers. We'd like you to help us by answering some questions. Your answers will be a big help to the people who create these materials. You may decide to quit or skip any questions that you don't feel comfortable answering.

Please enter the Student ID number that your teacher gave you:

What is RNA's function in a cell?

- ❍ Carry molecules
- ❍ Switch cellular machines on and off
- ❍ Carry coded messages from the nucleus to the ribosome
- ❍ All of the above

Which RNA bases bond together?

- ❍ Cytosine and Uracil
- ❍ Guanine and Cytosine
- ❍ Adenine and Cytosine
- ❍ All of the Above

What does the structure of the RNA determine?

- ❍ Its function
- ❍ Its food
- ❍ Its energy source
- ❍ All of the above

What is the correct order of assembly in the cell?

- ❍ DNA-protein-RNA
- ❍ DNA-RNA-protein
- ❍ Protein-RNA-DNA
- ❍ RNA-DNA-protein

How does RNA folding work?

Bases attract each other like magnets and form bonds. Bonds cause RNA to fold up into specific shapes.

RNA has several roles in the cell. What is special about RNA that allows it to be so versatile?

Folding allows RNA to change its structure. Different structures = Different functions

On a scale of 1 – 5, how interested are you in doing the following:

	1Not At All Interested	2	3	4	5Extremely Interested
Assisting with science research	❍	❍	❍	❍	❍
Working in a science-related career when you graduate	❍	❍	❍	❍	❍

Have you ever participated in research conducted by a scientist (taken a survey, shared your opinion with a researcher, participated in a medical study, etc.)?

❍ Yes
❍ No
❍ Not Sure

Do you play computer games in your free time?

❍ Yes
❍ No

How frequently do you play computer games?

❍ Everyday
❍ A few times a week
❍ Once or twice a week or less

When playing computer games, rate the following elements on a scale of 1 Not Necessary to 5 Essential:

	1Not Necessary	2	3	4	5Essential
Accumulating points	❍	❍	❍	❍	❍
Competing with others	❍	❍	❍	❍	❍
Hints from non-player characters	❍	❍	❍	❍	❍
Winning badges	❍	❍	❍	❍	❍
Unlocking different levels	❍	❍	❍	❍	❍
Playing a game that recognizes my login or player character	❍	❍	❍	❍	❍
Customizable features	❍	❍	❍	❍	❍
Able to see high scores on a leaderboard	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍

That's it! Thank you for your help.

Student Post-Assessment RNA Lab

Your classroom is testing some new materials during your class study of RNA. We want to understand how well they work for students and teachers. We'd like you to help us by answering some questions. Your answers will be a big help to the people who create these materials. You may decide to quit or skip any questions that you don't feel comfortable answering.

Please enter the Student ID number that your teacher gave you:

What is RNA's function in a cell?
- ❍ Carry molecules
- ❍ Switch cellular machines on and off
- ❍ Carry coded messages from the nucleus to the ribosome
- ❍ All of the above

Which RNA bases bond together?
- ❍ Cytosine and Uracil
- ❍ Guanine and Cytosine
- ❍ Adenine and Cytosine
- ❍ All of the Above

What does the structure of the RNA determine?
- ❍ Its function
- ❍ Its food
- ❍ Its energy source
- ❍ All of the above

What is the correct order of assembly in the cell?
- ❍ DNA-protein-RNA
- ❍ DNA-RNA-protein
- ❍ Protein-RNA-DNA
- ❍ RNA-DNA-protein

How does RNA folding work?

RNA has several roles in the cell. What is special about RNA that allows it to be so versatile?

On a scale of 1 – 5, how interested are you in doing the following:

	Not At All Interested	Uninterested	Neither Uninterested or Interested	Interested	Extremely Interested
Assisting with science research	❍	❍	❍	❍	❍
Working in a science-related career when you graduate	❍	❍	❍	❍	❍

Have you ever participated in research conducted by a scientist (taken a survey, shared your opinion with a researcher, participated in a medical study, etc.)?

❍ Yes
❍ No
❍ Not Sure

Compared to other activities you usually do in science class, how would you rate the RNA Lab? Compared to the usual schoolwork, I liked the RNA Lab:

❍ A lot less than usual schoolwork
❍ A little bit less than usual schoolwork
❍ About the same
❍ A little bit more than usual schoolwork
❍ A lot more than usual schoolwork

Please explain why you rated the RNA Lab this way.

Which trials did you complete? (check all that apply)

❑ Tutorial: The Basics
❑ Trial 1: Protein Synthesis
❑ Trial 2: RNA World
❑ Trial 3: Virus Attack
❑ I did not complete any of the game trials

How helpful was the VirtuaBot?

	1. Not At All Helpful	2	3	4	5. Very Helpful
How helpful was the VirtuaBot?	❍	❍	❍	❍	❍

Did you use the RNA Lab Wiki?

❍ Yes
❍ No
❍ Not Sure

Did you watch any of the RNA Lab videos?

❍ Yes
❍ No
❍ Not Sure

How much did you enjoy the RNA Lab videos?

❍ Not At All
❍ A Little
❍ Some
❍ A Lot

How motivated were you to continue playing the RNA Lab game?

- ❍ Not At All
- ❍ A Little
- ❍ Some
- ❍ A Lot

What motivated you to keep playing the game, if anything? (check all that apply)

- ❑ Solving puzzles
- ❑ Getting to the next trial of the game
- ❑ Unlocking videos
- ❑ Learning about RNA
- ❑ Helping scientists do their research
- ❑ Other (please tell us) _____

Did you play the RNA Lab game out of class?

- ❍ Yes
- ❍ No

What motivates you to play the RNA Lab game out of class?

Think about when you were using the online activities in the RNA Lab. How easy or hard was it to use the RNA Lab? Please tell us for each of the following:

	Very Hard	Hard	Neither Hard or Easy	Easy	Very Easy
Knowing where to start	❍	❍	❍	❍	❍
Knowing the goal of the activity	❍	❍	❍	❍	❍
Knowing what to click on to move the activity along	❍	❍	❍	❍	❍
Knowing where to get help when you needed it	❍	❍	❍	❍	❍
Knowing when you were done	❍	❍	❍	❍	❍

When you were playing the RNA Lab game, how successful were you at completing the trials? Please tell us how you felt for each of the trials you completed.

	Did Not Do That Activity	Not at all successful	Not very successful	Somewhat successful	Mostly Successful	Totally Successful
Tutorial: The Basics	❍	❍	❍	❍	❍	❍
Trial 1: Protein Synthesis	❍	❍	❍	❍	❍	❍
Trial 2: RNA World	❍	❍	❍	❍	❍	❍
Trial 3: Virus Attack	❍	❍	❍	❍	❍	❍

When you were playing the RNA Lab, did you know that your RNA pairing could have helped scientists with their research?

- ❍ Yes
- ❍ No
- ❍ Not Sure

What was your favorite part of the RNA Lab? Why?

What was your least favorite part of the RNA Lab? Why?

Now that you've used the RNA Lab, would you do any of the following: (choose all that apply)

- ❑ I would use it, or another NOVA Lab, for a school project/assignment
- ❑ I would continue exploring it, or another NOVA Lab, on my own, even though the assignment is complete
- ❑ I would tell a friend about this site, or another NOVA Lab
- ❑ I wouldn't do any of the above

Would you share this game with your friends on social media?

- ❍ Yes
- ❍ No

Please share why you wouldn't share this game on social media.

One last question, is there anything we can do to improve the RNA Lab for students like you?

That's it! Thank you for your help.

Interview Guide: Teacher Interviews

September 18, 2014

Interview Guide

Thank you for making time to talk with me today about your experience with NOVA Labs.

I work for an evaluation firm, the Lifelong Learning Group, and we are working with NOVA Education to understand what is working well and what could be improved about NOVA Labs. This discussion will be kept confidential; I will not include your name or any identifying details with the comments I share with NOVA Education.

Before we begin, do you have any additional questions? [answer any questions]

I would also like to audio record our conversation, if that's OK with you. We will transcribe the recording after we're done, and then the recording will be deleted. Do you agree to continue with the interview and allow audio recording? [if no, interviewer will take notes instead]

Labs in Practice

1. To start, can you share a little information about the setting where you teach and the class you used the site with? [prior to interview insert information gained during email exchanges]

2. I'd like to hear about how your use of the RNA Lab went this semester?

   Topics for follow-up / to be sure to cover – "Why did you decide to do that":
   a. Which parts of the Lab you used?
   b. How did students use the interface – individually, small groups, as a whole-class?
   c. Were students assigned to use the site at home? How often was it assigned?
   d. Was the project part of a bigger unit, stand-alone?
   e. In what ways did you integrate it into the rest of your curriculum?
      - Was this easy to do / a natural fit?
      - What were the challenges you faced in implementing the lab in this way?
      - How did it impact other aspects of your curriculum?
   f. What other activities or extensions did you do with students *other than* the online interface – if any?
   g. Do you think having the Lab as a resource make it easier or more difficult for you to teach RNA in the classroom? Why?

Overall Response and Feedback:

3. What about the RNA Lab was most useful to your teaching?

   → Overall educational value
   → Engaging for students
   → Professional quality
   → Easy for students to use
   → Alignment with standards

4. How well suited, or not, was the Lab to your students' abilities?
   → What additional directions do students need to be successful?
   → Which students, if any, were unable to use the Lab?
   → % that found it easy, Why?
   → % that found it overwhelming, Why?

5. How did including the RNA Lab in your classroom change or add to your normal teaching or curriculum?

6. What do you think might be improved about the concept of NOVA Labs to make it more useful?
   → How would that improvement support you in teaching?

Students

7. Did you have a chance to speak to your students?
   → Was it fun for the students to play the game?
   → What motivated them, if anything, to keep playing the game?
   → What did they like best and least about the RNA Lab?
   → Was the RNA Lab more or less helpful to them in learning about how RNA works in the cell when compared to your typical teaching methods?

8. What did students respond to most positively in the RNA Lab?

9. What seemed to keep them most interested or engaged?
   → The narrative element of the Lab
   → Videos
   → Leveling up
   → The fun of solving the puzzles

10. Did your students find any aspects of the Lab challenging? If so, which ones?

    → technology
    → formatting
    → content
    → tasks

11. What were the main student learning outcomes that you observed in your classroom?

- ➔ Aware of STEM careers
- ➔ Aware of the type of work that scientists/engineers do
- ➔ Increased interest in pursuing education in STEM
- ➔ Scientific process skills
- ➔ Understanding of principles of weather
- ➔ Understanding of role of engineering

Focus on Specific Resources

Video Library

12. Which videos did you use? How did you incorporate them?

13. What did you like most about the videos as a classroom resource?

14. How could these videos be improved to be more useful for you?

RNA Lab Game Levels/Trials

15. Which levels/trials did you use with your students?

16. What did you like most about the RNA Lab Activities as a classroom resource?

17. What would you change to increase the usefulness of this resource for your classroom?

Educator Guide

18. Did you use the Educators' Guide at all?

19. What information in this section was the most helpful to you?

20. What additional information would you like to see in Educator Resources?

Wrap-up

21. Finally, as you think about the RNA Lab and the NOVA Labs concept, are there any other changes or enhancements that could be made to make the site more valuable to your teaching?

That's it. Thank you so much for your time and participation in this discussion. Your feedback has been incredibly helpful and will help improve the development of these resources.

Appendix B: Supporting Data Tables

Technology available to test group teachers and students

Class	Technology Available
A	Chromebooks
B	Laptops
C	Laptops
D	Tablets
E	Computers

Frequency/Percentage of students who successfully completed each trial

	School A	School B	School C	School D	School E	Total
Tutorial	101 (86%)	21 (100%)	39 (87%)	13 (77%)	14 (88%)	188 (87%)
Protein	83 (71%)	21 (100%)	37 (82%)	14 (82%)	15 (94%)	170 (79%)
RNA	37 (32%)	14 (67%)	29 (64%)	10 (59%)	16 (100%)	106 (49%)
Virus	7 (6%)	7 (34%	10 (22%)	1 (6%)	7 (44%)	32 (15%)
None	4 (3%)	0	1 (2%)	0	0	5 (2%)

Appendix C: Post Survey of Teachers Addendum

In an effort to gather a broader sample of teacher feedback about the RNA Lab, teachers who had responded to the earlier recruitment invitation for test-classes were invited to complete an online survey. It was assumed these teachers were inclined to use the Lab in their classroom since they had responded to the earlier recruitment invitation. This survey was distributed to 82 teachers through e-mails sent from the web-based survey platform. Additionally, it was distributed to teachers through NOVA social media.

Timing seems to have made data collection challenging for some teachers; many of the teachers who had declined to participate as a test-class indicated RNA was not taught until spring semester. In order to include as many teachers who had used the Lab as possible, data collection for this instrument remained open until mid-February 2015. Therefore, data from that instrument were not incorporated into the report, rather they are included here as an addendum.

Findings

Data were collected from 16 teachers who responded to the RNA Lab post-teacher survey: six who used the RNA Lab with their students and ten who did not. Teachers whoused the Lab with their students will be referred to as "Users" throughout this addendum, while teachers who did not use the Lab with their students will be referred to as "Non-Users." Of the six users, only three answered all questions, but due to the limited number of respondents, all available data were used in the data analysis.

Non-Users were likely to be high school teachers (8 of 10 Non-Users); these respondents taught general science (5) and/or life science (6). Non-users indicated they did not use the Lab with their students for the following reasons:

- They do not study RNA until later in the year (5)
- They weren't aware of the Lab (3)
- They ran out of time(1)
- They were "confused by painting the RNA" and "thought [their] students would too" (1)

Respondents were likely to be high school teachers (3 of 4 Users) who taught life science (3) or biotechnology (1). Five Users indicated they fit the RNA Lab into their curriculum without an adjustment. Four respondents indicated that students worked on the Lab in their classroom (3 reporting this as individual work and 1 reporting it as small group work). One teacher assigned it as a take-home extra credit assignment.

Three of the Users showed one or more of the videos to the whole class, while one assigned specific videos for students to watch on their own. Only one user did not use the video resources. Three users believed the videos were fine, indicating they liked the length, graphics, content, age-appropriateness, and quality of the videos equally.

All five Users who answered the question reported using the first two game levels of the RNA Lab, The Basics and Protein Synthesis; four went beyond the first two levels, also assigning the RNA World level. Two used the Virus Attack level with their students. All respondents (5 Users) felt that at least 50 – 74% of their students completed the levels assigned; one believed all of his/her students were able to complete the activity successfully. Just over half of respondents (3 of 5 Users) indicated they used the Lab Educator Guide.

The Users rated the Lab highly, with all six respondents rating the Lab Good to Very Good for the following statements:

- Overall educational value
- Engaging for students
- Professional quality of materials
- Easy for students to use
- Alignment with curriculum standards.

Respondents believed their student's favorite part of the Lab was the "game-like experience" (2 Users) and "figuring out the code" (1 User). Two Users felt their students struggled when moving to higher levels, but caught on after a few minutes. One User suggested a quick video tutorial might help confused students. Two Users indicated they assessed student takeaways from the Lab: one asked students questions about the lab and the other had students "write two good questions that came from the experience."

All five responding Users rated the RNA Lab as "Better" to "Much Better" when compared to other resources in the following ways:

- Teaching students important RNA concepts
- Keeping students engaged and interested in learning more about the topic

All four responding Users agreed that due to using NOVA Labs their students achieved the following outcomes:

- Became more aware of specific careers in STEM (science, technology, engineering, or math)
- Became more aware of the type of work that scientists and engineers do
- Increased their interest in pursuing education in STEM
- Increased their interest in pursuing a career in STEM
- Demonstrated ability to ask questions and define problems
- Demonstrated ability to plan and carry out an investigation
- Demonstrated ability to analyze and interpret data
- Demonstrated ability to use mathematics and computational thinking
- Demonstrated ability to construct explanations or design solutions, based on data

Users rated the content, tone and activities of the Lab either "about right for students", or above students' level. No user felt the content, tone or activities was below their students' level.

	About right for students	Somewhat above students' level	Far above students' level
Content addressed	3	1	1
Grade-level fit	2	2	1
Complexity or depth of material covered	3	2	0
Tasks or skills required of students	0	2	3

N=5

Respondents (both Users and Non-Users) learned about the WGBH NOVA RNA Lab through the following channels:

- NOVA Education newsletter (SPARK) (6)

- An internet search (4)
- NOVA social media (Facebook, Twitter, etc.) (4)
- Link on the NOVA Education website (3)
- Word of mouth - recommended by a friend/colleague (1)

Respondents indicated students in their classes use technology in the following ways:

- Conduct online research (11)
- Use educational games (10)
- Communicate with peers or teachers (9)
- Produce print products (8)
- Visually represent or investigate concepts (8)
- Use digital tools and peripheral devices in their school work (8)
- Produce multi-media, Web, or presentation products (7)
- Solve real-world problems (7)
- Use drill and practice or tutorial software (5)
- Use the Internet to collaborate with students in or beyond your school (4)
- Communicate with experts (3)

Respondents were working hard to improve their teaching effectiveness. They reported the having done the following activities during the past year:

- Eleven attended a conference or class-either online or face to face
- Eleven sought online resources to increase my knowledge and/or effectiveness
- Eight created resources (videos, wikis, etc) to share my ideas with others
- Seven sought out a 1 to 1 experience with other teachers or content knowledge experts
- Seven used a mobile application to increase my knowledge and/or effectiveness
- Five used social media to communicate or follow others.

More detail about teachers' specific professional development activities is included below.

11 respondents who indicated they attended a conference

Ten attended a face to face conference.
Eight participated in a webinar or online conference.
Five took a self-paced tutorial on a subject.
Four took an online course.

11 respondents who indicated they sought online resources

Nine found information on the internet to help them prepare/deliver a lesson.
Nine listened to podcasts or watched videos about topics they were interested in.
Four took online assessments to test my own knowledge on a subject.
Four took part in an online game or simulation.
Three posted a question to a blog or wiki.

7 respondents who indicated they sought out a 1 to 1 experience

Five provided online support to other teachers.
Three worked with a mentor online.

Two worked with an expert in their school or community.
Two worked with an experts online who could answer their questions.
Two sought help from other teachers through a social networking site.
One worked with a mentor in his/her school or community.

8 respondents who created resources to share with others

Two created a video.
Two created a Wiki.
Two created a Blog.