

Supplementary Materials for

Title: Adolescents' knowledge of and confidence in vaccines improves with board game play

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Fig. S1. Frequency with which students played board or card games ($n = 286$).

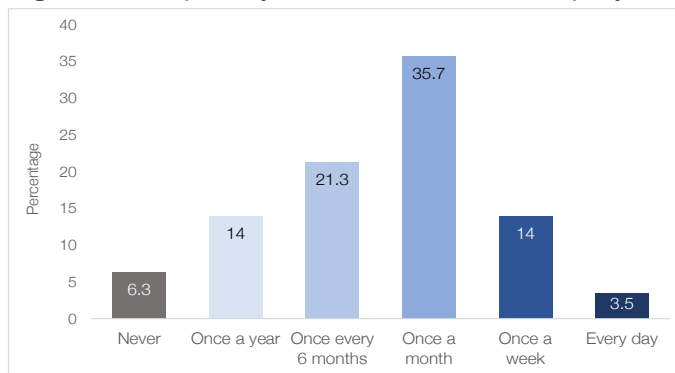
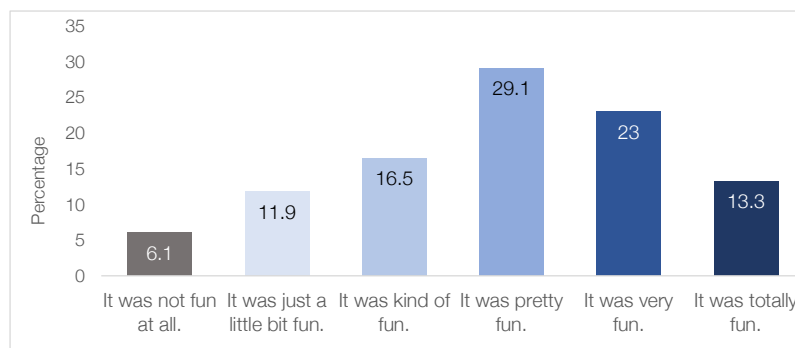


Fig. S2. Students' enjoyment of N.O.V.E.L. ($n = 278$)



Students' comments on enjoyment¹ included the following:

- "I had fun. It's a great game to play. It can be very informational."
- "It was very fun and challenging."
- "I had a fun time learning about diseases and vaccines."
- "It was a good bonding experience with my group of friends."
- "Education games are fun."
- "Playing N.O.V.E.L. was a great experience. I would love to play it again if I could in the future."

Student Stressors in 2019 before COVID-19 and in 2020 during Lockdown.

¹ Responses to the question "Is there anything else that you would like to tell us about your experience playing N.O.V.E.L.?"

For this aspect of the study, we used a formative survey of students in 5th through 8th grade exploring their stressors in 2019 before the SARS-CoV2 COVID-19 pandemic and separately during the COVID-19 lockdown in 2020. Similarly, we surveyed parents and teachers about what they perceived to be the stressors for students. During the COVID-19 lockdown, 67% (N=21) of the students indicated that they were experiencing more stress. The data represents the average of perceived stressors among the students, and reveals major disconnects exist between what students are reporting and what their parents and teachers think they are stressed about. A mixed-methods approach targeted four different participant populations: 5th-8th grade students; parents of 5th-8th grade students; 5th-8th grade teachers, and other school staff (merged with teachers). In the study, both quantitative data and qualitative data were collected. Survey instruments were developed by the authors and implemented by Camellia W. Sanford-Dolly, Ph.D. of Rockman et al Cooperative, Inc. with an approved IRB. A total of sixty-seven individuals (22 students, 36 parents, and 9 teachers) participated in the surveys before COVID-19 and 69 (19 students, 26 parents, and 26 teachers) during the COVID-19 pandemic. Study participants were recruited via email and social media posts. Consent was granted by those participants over 18 years of age, while parental consent and student assent was granted for participants under 18 years of age.

Student survey respondents were asked to rate 27 potential stressors in their lives on a scale from 1 to 10, with 1 being “This doesn’t stress me out at all,” and 10 being “I’m stressed about this all the time.” The biggest stressors noted by participating students who took the survey before COVID-19 were school and taking tests (**Table S1**) and during COVID-19, the biggest stressors on students were school, others’ health and speaking up in class (**Table S1**).

The biggest stressors parents felt their students had before COVID-19 were friends, and immediate family, representing a significant mismatch between what parents’ thought were the biggest stressors for their children and what was stressful for students (**Table S2**). During COVID-19, parents’ perception of students’ stress was lower than what the students themselves experienced, such that students rated almost all stressors as being more stressful than how the parents rated them (21 higher, 4 lower, and 2 essentially unchanged; **Table S3**).

Like parents, there was a mismatch between what teachers thought were the biggest stressors for their students and what was stressful for students before the pandemic (**Table S4**). However, unlike parents, teachers’ perceptions of students’ stress were higher than what the students themselves experienced both before (20 lower, 4, higher, 3 essentially unchanged) and during COVID-19 (18 lower, 7 higher and 7 essentially unchanged; **Table S5**).

Table S1: Students' Self-Reported Stressors Before & During COVID-19

Potential Stressors	Mean Before COVID (N=22)	Mean During COVID (N=18)	Difference Before & During COVID	Perceived Stress During COVID
School	5.95	6.22	+ 0.27	HIGHER 
Taking tests, exams, or quizzes	5.55	5.06	- 0.49	LOWER 
Others' health	4.95	5.33	+ 0.38	HIGHER 
Speaking up/ Participating in class	4.50	5.28	+ 0.78	HIGHER 
Immediate family	4.27	4.56	+0.29	HIGHER 
Friends	4.23	3.67	- 0.56	LOWER 
My grades	4.23	4.89	+0.66	HIGHER 
Teachers	4.18	4.61	+ 0.43	HIGHER 
Bullying	4.14	3.17	- 0.97	LOWER 
Physical appearance	4.00	4.50	+ 0.50	HIGHER 
My own health	3.95	4.50	+ 0.55	HIGHER 
Extended family	3.68	2.72	- 0.96	LOWER 
Sports	3.59	4.17	+ 1.11	HIGHER 
Communicating with other people	3.45	2.94	- 0.51	LOWER 
Social events/ Group settings	3.36	4.06	+ 0.70	HIGHER 
Responsibilities/Chores	3.27	3.33	0.06	SAME 
Environment	3.09	3.89	+ 0.80	HIGHER 
Preparing for college	3.00	4.28	+ 1.28	HIGHER 
Figuring out what I want to do with my life	2.95	4.61	+ 1.66	HIGHER 
Relationships/Dating	2.91	3.28	+ 0.37	HIGHER 
Food/Nutrition	2.91	2.78	0.13	SAME 
Pets	2.64	4.28	+ 1.64	HIGHER 
Job/ Employment	2.59	2.11	- 0.48	LOWER 
Money	2.50	3.33	+ 0.83	HIGHER 
Food availability	2.27	1.56	- 0.71	LOWER 
Religion	1.95	2.44	+ 0.49	HIGHER 
Politics	1.71	4.33*	+2.62	HIGHER 

* Indicates a significant difference at the $p < .05$ level.

Table S2: Parents' Perceptions of Students' Stressors, Compared to Students' Stressors Before COVID-19

Potential Stressors	Parents' Mean (N=29)	Students' Mean (N=22)	Students' Self-Report Compared to Parents' Perceptions	
Friends	6.10	4.23*	- 1.87	LOWER 
Immediate family	5.83	4.27*	- 1.56	LOWER 
School	5.69	5.95	+ 0.26	HIGHER 
Bullying	5.10	4.14	- 0.96	LOWER 
Social events/ Group settings	5.03	3.36	- 1.67	LOWER 
Taking tests, exams, or quizzes	4.97	5.55	+ 0.58	HIGHER 
Speaking up/ Participating in class	4.66	4.50	- 0.16	LOWER 
Physical appearance	4.38	4.00	- 0.38	LOWER 
Teachers	4.14	4.18	+ 0.04	SAME 
Responsibilities/Chores	4.04	3.27	- 0.77	LOWER 
Communicating with other people	4.03	3.45	- 0.58	LOWER 
Grades	4.03	4.23	+ 0.20	HIGHER 
Others' health	3.79	4.95	+ 1.16	HIGHER 
Sports	3.50	3.59	+ 0.09	SAME 
Figuring out what they want to do with their lives	3.38	2.95	- 0.43	LOWER 
Their own health	3.24	3.95	+ 0.71	HIGHER 
Extended family	3.17	3.68	+ 0.61	HIGHER 
Pets	2.97	2.64	- 0.33	LOWER 
Relationships/Dating	2.83	2.91	+ 0.08	SAME 
Money	2.83	2.50	- 0.33	LOWER 
Environment	2.64	3.09	+ 0.45	HIGHER 
Food/Nutrition	2.38	2.91*	+ 0.53	HIGHER 
Politics	2.25	1.71*	+ 0.54	HIGHER 
Preparing for college	2.24	3.00	+ 0.76	HIGHER 
Religion	1.89	1.95	+ 0.06	SAME 
Job/ Employment	1.14	2.59*	+ 1.45	HIGHER 
Food availability	1.10	2.27	+ 1.17	HIGHER 

* Indicates a significant difference at the $p < .05$ level.

Table S3: Parents' Perceptions of Students' Stressors, Compared to Students' Actual Stressors During COVID-19

Potential Stressors	Parents' Mean (N=21-25)	Students' Mean (N=18)	Students' Self-Report Compared to Parents' Perceptions
School	5.62	6.22	+ 0.60 HIGHER 
Taking tests, exams, or quizzes	5.00	5.06	+ 0.06 SAME 
Friends	4.95	3.67	- 1.28 LOWER 
Teachers	4.33	4.61	+ 0.28 HIGHER 
Immediate family	3.88	4.56	+ 0.68 HIGHER 
Speaking up/ Participating in class	3.86	5.28	+ 1.42 HIGHER 
Physical appearance	3.71	4.50	- 0.79 LOWER 
Grades	3.48	4.89	+ 1.41 HIGHER 
Bullying	3.38	3.17	- 0.21 LOWER 
Politics	3.38	4.33	+ 0.95 HIGHER 
Others' health	3.29	5.33*	+ 2.04 HIGHER 
Responsibilities/Chores	3.05	3.33	+ 0.28 HIGHER 
Social events/ Group settings	2.90	4.06	+ 1.16 HIGHER 
Environment	2.81	3.89	+ 1.08 HIGHER 
Their own health	2.71	4.50*	+ 1.79 HIGHER 
Figuring out what they want to do with their lives	2.62	4.61*	+ 1.99 HIGHER 
Sports	2.48	4.17*	+ 1.69 HIGHER 
Preparing for college	2.33	4.28*	+ 1.95 HIGHER 
Communicating with other people	2.29	2.94	+ 0.65 HIGHER 
Money	2.24	3.33	+ 1.09 HIGHER 
Food/Nutrition	2.19	2.78	+ 0.59 HIGHER 
Extended family	2.14	2.72	+ 0.58 HIGHER 
Relationships/Dating	2.00	3.28	+ 1.28 HIGHER 
Pets	2.00	4.28*	+ 2.28 LOWER 
Religion	1.62	2.44	+ 0.82 HIGHER 
Food availability	1.48	1.56	+ 0.08 SAME 
Job/ Employment	1.33	2.11	+ 0.78 HIGHER 

* Indicates a significant difference at the $p < .05$ level.

Table S4: Teachers' Perceptions of Students' Stressors, Compared to Students' Stressors Before COVID-19

Potential Stressors	Teachers' Mean (N=9)	Students' Mean (N=22)	Students' Self-Report Compared to Teachers' Perceptions
Friends	9.00	4.23*	- 4.77 LOWER 
School	7.56	5.95	- 1.61 LOWER 
Immediate family	7.33	4.27*	- 3.06 LOWER 
Bullying	7.22	4.14*	- 3.08 LOWER 
Taking tests, exams, or quizzes	7.00	5.55	- 1.45 LOWER 
Social events/ Group settings	6.56	3.36*	- 3.20 LOWER 
Physical appearance	6.56	4.00*	- 2.56 LOWER 
Grades	6.56	4.23	- 2.33 LOWER 
Sports	6.56	3.59*	- 2.97 LOWER 
Relationships/Dating	5.78	2.91*	- 2.87 LOWER 
Teachers	5.44	4.18	- 1.26 LOWER 
Communicating with other people	5.44	3.45	- 1.99 LOWER 
Extended family	5.22	3.68	- 1.54 LOWER 
Food availability	4.67	2.27*	- 2.40 LOWER 
Speaking up/ Participating in class	4.56	4.50	- 0.06 SAME 
Figuring out what they want to do with their lives	4.22	2.95	- 1.27 LOWER 
Money	4.11	2.50	- 1.61 LOWER 
Preparing for college	4.00	3.00	- 1.00 LOWER 
Environment	3.67	3.09	- 0.58 LOWER 
Food/Nutrition	3.67	2.91	- 0.76 LOWER 
Others' health	3.29	4.95	+ 1.66 HIGHER 
Responsibilities/Chores	3.22	3.27	+ 0.05 SAME 
Politics	2.56	1.71*	- 0.85 LOWER 
Their own health	2.44	3.95	+ 1.51 HIGHER 
Pets	1.89	2.64	+ 0.75 HIGHER 
Religion	1.89	1.95	+ 0.06 SAME 
Job/ Employment	1.89	2.59	+ 0.70 HIGHER 

* Indicates a significant difference at the $p < .05$ level.

Table S5: Teachers' Perceptions of Their Students' Stressors, Compared to Students' Stressors During COVID-19

Potential Stressors	Teachers' Mean (N=21-25)	Students' Mean (N=22)	Students' Self-Report Compared to Teachers' Perceptions
Friends	7.14	3.67*	- 3.47 LOWER 
Physical appearance	6.95	4.50*	- 2.45 LOWER 
School	6.76	6.22	- 0.54 LOWER 
Taking tests, exams, or quizzes	6.62	5.06	- 1.56 LOWER 
Social events/ Group settings	6.33	4.06*	- 2.27 LOWER 
Food availability	6.00	1.56*	- 4.44 LOWER 
Speaking up/ Participating in class	5.95	5.28	- 0.67 LOWER 
Extended family	5.95	2.72*	- 3.23 LOWER 
Grades	5.81	4.89	- 2.33 LOWER 
Immediate family	5.68	4.56	- 1.12 LOWER 
Bullying	5.67	3.17*	- 2.50 LOWER 
Sports	5.52	4.17	- 2.97 LOWER 
Teachers	5.29	4.61	- 0.68 LOWER 
Relationships/Dating	5.19	3.28*	- 1.91 LOWER 
Communicating with other people	5.10	2.94*	- 2.16 LOWER 
Money	5.05	3.33	- 1.72 LOWER 
Figuring out what they want to do with their lives	4.19	4.61	+ 0.42 HIGHER 
Their own health	4.14	4.50	+ 0.36 HIGHER 
Others' health	3.90	5.33	+ 1.43 HIGHER 
Preparing for college	3.81	4.28	+ 0.47 HIGHER 
Environment	3.81	3.89	+ 0.08 SAME 
Politics	3.71	4.33	+ 0.62 HIGHER 
Food/Nutrition	3.43	2.78	- 0.65 LOWER 
Pets	3.05	4.28	+ 1.23 HIGHER 
Responsibilities/Chores	3.00	3.33	+ 0.33 HIGHER 
Job/ Employment	2.71	2.11	- 0.60 LOWER 
Religion	2.43	2.44	+ 0.01 SAME 

* Indicates a significant difference at the $p < .05$ level.

Statistical Tables, Aggregated Results

Students significantly improved their knowledge about how vaccines are made ($t(262) = -10.15, p < .001$, Cohen's $d = 0.63$). On average, their scores increased 3.36 points (13.6%) from pre to post (Figure 3).

Table S6. Vaccine content knowledge scores before and after playing N.O.V.E.L.

Survey	<i>M</i>	<i>SD</i>	<i>t</i> (262)	<i>p</i>	Effect size (Cohen's <i>d</i>)
Pre	24.64	5.04	10.15	<.001	0.63
Post	27.99	5.29			

Table S7. Changes in vaccine content knowledge scores, by grade, gender, and race/ethnicity.

Characteristic	<i>n</i>	Percentage correct		<i>t</i>	<i>df</i>	<i>p</i>	Effect size (Cohen's <i>d</i>)
		<i>M</i>	<i>SD</i>				
Types							
Pre	263	34.93	21.10	9.33	262	<.001	0.58
Post	263	53.05	28.54				
Ingredients							
Pre	263	38.67	19.74	7.69	262	<.001	0.47
Post	263	53.12	26.70				
Species on which vaccines are tested							
Pre	262	36.86	15.59	34.21	261	<.001	2.11
Post	262	81.97	17.14				

Table S8. Vaccine content knowledge scores before and after playing N.O.V.E.L., by student background and demographic characteristics.

Characteristic	<i>n</i>	Pre		Post		
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Grade						
Middle school (grades 7 – 8)	204	23.96	5.24	27.75	5.55	
High school (grades 9 – 11)	59	26.98	3.38	28.86	4.17	
Gender						
Male	127	23.94	5.15	27.51	5.56	
Nonmale	136	25.28	4.87	28.45	4.99	
Race						
All other races/ethnicities	224	24.88	4.98	28.33	5.12	
Underrepresented in STEM ¹	39	23.21	5.19	26.05	5.88	
Frequency of board gameplay						
Never	17	21.71	6.37	25.18	4.86	
Once a year	39	25.21	4.60	28.69	5.11	
Once every six months	55	24.60	4.75	27.55	5.87	
Once a month	93	24.83	4.99	28.34	4.98	
Once a week	51	24.69	5.05	28.06	5.33	
Every day	8	25.75	5.90	29.25	5.26	
Game performance						
Won the game	223	24.61	5.01	28.18	5.10	
Did not win the game	12	24.00	6.55	26.08	8.14	
Did not finish	25	24.96	4.55	27.04	5.33	

¹ Races underrepresented in STEM = Black/African American, Hispanic American/Latino(a), Native Alaskan, Native American, and Pacific Islander, or any combination of the above (National Institutes of Health, 2019).

Table S9. Changes in vaccine content knowledge scores, by grade, gender, and race/ethnicity

Characteristic	<i>n</i>	Change		<i>t</i>	<i>df</i>	<i>p</i>	Effect size (Cohen's d)
		<i>M</i>	<i>SD</i>				
Grade							
Middle school (grades 7 – 8)	204	3.79	5.72	3.10	151	.001	0.36
High school (grades 9 – 11)	59	1.88	3.59				
Gender							
Male	127	3.57	5.32	0.60	261	.275	0.07
Nonmale	136	3.17	5.43				
Race/Ethnicity							
All other races/ethnicities	224	3.45	5.40	0.65	261	.259	0.11
Underrepresented in STEM ¹	39	2.85	5.24				

¹ Races underrepresented in STEM = Black/African American, Hispanic American/Latino(a), Native Alaskan, Native American, and Pacific Islander, or any combination of the above (National Institutes of Health, 2019)

Table S10. Changes in vaccine content knowledge scores, by gameplay frequency and performance

Characteristic	<i>n</i>	Change		<i>F</i>	<i>df</i>	<i>p</i>	Effect size (Eta squared)
		<i>M</i>	<i>SD</i>				
Frequency of board gameplay							
Never	17	3.47	8.06	0.09	1,5	.994	0.002
Once a year	39	3.49	5.20				
Once every six months	55	2.95	5.18				
Once a month	93	3.52	4.71				
Once a week	51	3.37	5.81				
Every day	8	3.50	6.57				
Game performance							
Won the game	223	3.58	5.39	1.23	1,2	.295	0.01
Did not win the game	12	2.08	7.46				
Did not finish the game	25	2.08	4.04				

Table S11. Vaccine content knowledge confidence before and after playing N.O.V.E.L.

Survey	<i>kM</i>	<i>SD</i>	<i>t</i> (257)	<i>p</i>	Effect size (Cohen's <i>d</i>)
Pre	3.28	1.04	7.77	<.001	0.48
Post	3.87	1.12			

Table S12. Perceptions of vaccine safety and effectiveness, before and after playing N.O.V.E.L.

Statement	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i> ¹	Effect size (Cohen's <i>d</i>)
Lots of research goes into develop a vaccine before it is released to the public.							
Pre	262	5.56	0.92	1.85	261	.33	0.11
Post	262	5.68	0.62				
Getting vaccinated is a safe way to protect yourself from disease.							
Pre	263	4.91	1.38	1.17	262	.12	0.07
Post	263	4.99	1.28				
Human testing of vaccines ensures that new vaccines are safe to use.							
Pre	263	4.50	1.40	3.23	262	<.001	0.20
Post	263	4.79	1.30				
I am concerned about the safety of newly developed vaccines.							
Pre	259	3.62	1.62	0.24	258	.41	0.14
Post	259	3.64	1.64				
Vaccines contain harmful substances.							
Pre	262	3.21	1.45	-0.45	261	.33	0.09
Post	262	3.17	1.43				
Healthy people do not need to get vaccinated.							
Pre	261	2.20	1.48	0.22	260	.41	0.01
Post	261	2.21	1.59				

¹ Threshold for statistical significance is .008 (Bonferroni-adjusted alpha of .05/6 item comparisons)

Table S13. Importance of selected soft skills for being a “good scientist,” before and after playing N.O.V.E.L.

Characteristic	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i> ¹	Effect size (Cohen's <i>d</i>)
Being a good communicator							
Pre	256	5.04	0.97	2.54	255	.006	0.16
Post	256	5.21	0.94				
Being competitive							
Pre	253	2.53	1.33	3.87	252	<.001	0.24
Post	253	2.91	1.57				
Being cooperative							
Pre	250	5.31	0.84	1.25	249	.106	0.08
Post	250	5.40	0.84				
Being independent							
Pre	254	3.81	1.4	2.23	253	.013	0.14
Post	254	4.00	1.52				
Being able to follow the rules							
Pre	254	5.30	1.07	0.46	253	.324	0.03
Post	254	5.33	1.1				
Being creative							
Pre	258	4.84	1.18	-0.45	257	.326	-0.03
Post	258	4.80	1.21				
Sharing resources							
Pre	259	4.78	1.04	5.52	258	<.001	0.34
Post	259	5.17	0.93				
Collaborating to create vaccines							
Pre	259	5.33	0.85	-1.17	258	.121	-0.07
Post	259	5.26	0.88				

¹ Threshold for statistical significance is .006 (Bonferroni-adjusted alpha of .05/8 item comparisons)

Table S14. Importance of selected soft skills for being a “good scientist” and for playing N.O.V.E.L.

Characteristic	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i> ¹	Effect size (Cohen's <i>d</i>)
Being a good communicator							
For scientists, (post survey)	256	5.21	0.94	0.67	255	.251	0.04
For playing N.O.V.E.L.	256	5.16	0.98				
Being competitive							
For scientists, (post survey)	253	2.91	1.57	0.26	252	.398	0.02
For playing N.O.V.E.L.	253	2.88	1.71				
Being cooperative							
For scientists, (post survey)	250	5.40	0.84	1.48	249	.070	0.09
For playing N.O.V.E.L.	250	5.28	1.5				
Being independent							
For scientists, (post survey)	254	4.00	1.52	5.79	253	<.001	0.36
For playing N.O.V.E.L.	254	3.43	1.58				
Being able to follow the rules							
For scientists, (post survey)	254	5.33	1.10	-2.24	253	.010	-0.14
For playing N.O.V.E.L.	254	5.48	0.89				
Being creative							
For scientists, (post survey)	258	4.80	1.21	-4.77	257	<.001	-0.30
For playing N.O.V.E.L.	258	4.38	1.45				

¹ Threshold for statistical significance is .008 (Bonferroni-adjusted alpha of .05/6 item comparisons)

Statistical Tables for the Case Study

Table S15. Stacie's students' mean ratings of the importance of soft skills for being a good scientist before and after playing N.O.V.E.L.

Characteristic	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i> ¹	Effect size (Cohen's <i>d</i>)
Being a good communicator							
Pre	88	4.82	1.12	2.68	87	.004	0.29
Post	88	5.16	0.98				
Being competitive							
Pre	89	2.57	1.37	1.68	88	.048	0.18
Post	89	2.88	1.57				
Being cooperative							
Pre	88	5.17	0.89	2.69	87	.004	0.29
Post	88	5.47	0.74				
Being independent							
Pre	86	3.76	1.46	2.17	85	.016	0.23
Post	86	4.15	1.63				
Being able to follow the rules							
Pre	89	5.47	0.83	1.30	88	.10	0.14
Post	89	5.58	0.70				
Being creative							
Pre	89	4.82	1.20	0.45	88	.32	0.05
Post	89	4.88	1.13				
Sharing resources							
Pre	91	4.73	1.06	3.48	90	<.001	0.37
Post	91	5.13	0.90				
Collaborating to create vaccines							
Pre	90	5.22	0.91	-0.28	89	.39	-0.03
Post	90	5.19	0.90				

¹ Threshold for statistical significance is .006 (Bonferroni-adjusted alpha of .05/8 item comparisons)

Table S16. Perceptions of vaccine safety and effectiveness, before and after playing N.O.V.E.L.

Statement	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i> ¹	Effect size (Cohen's <i>d</i>)
Lots of research goes into develop a vaccine before it is released to the public.							
Pre	90	5.38	1.18	0.89	89	.19	0.09
Post	90	5.50	0.77				
Getting vaccinated is a safe way to protect yourself from disease.							
Pre	91	4.40	1.58	1.05	90	.15	0.11
Post	91	4.53	1.45				
I am concerned about the safety of newly developed vaccines.							
Pre	88	4.13	1.50	-0.34	87	.37	-.04
Post	88	4.07	1.57				
Human testing of vaccines ensures that new vaccines are safe to use.							
Pre	91	4.05	1.61	1.74	90	.04	0.18
Post	91	4.36	1.45				
Vaccines contain harmful substances.							
Pre	90	3.46	1.46	-0.39	90	.35	0.04
Post	90	3.40	1.47				
Healthy people do not need to get vaccinated.							
Pre	89	2.90	1.65	-0.26	88	.40	-0.03
Post	89	2.85	1.73				

¹ Threshold for statistical significance is .008 (Bonferroni-adjusted alpha of .05/6 item comparisons)

Survey Instruments

Item Scoring

Table S17. Overview of vaccine development item scoring.

Item type	Scoring
Single answer multiple choice or true/false	Correct answer = 4 points Incorrect answer = 0 points
Multiple answer, “check-all-that-apply” (vaccine types, ingredients, and testable animals)	<u>Step 1:</u> 1 point for every correct answer checked and every incorrect answer NOT checked <u>Step 2:</u> Sum scores <u>Step 3:</u> Convert sum scores to a four-point scale to ensure even weighting of items across the survey. <u>For vaccine types and ingredients (7 options)</u> 4 points = Sum of 7 (all correct answers and no incorrect answers selected) 3 = Sum of 5 or 6 2 = Sum of 3 or 4 1 = Sum of 1 or 2 0 = Sum of zero <u>For animals (12 options)</u> 4 points = Sum of 12 (all correct answers and no incorrect answers selected) 3 = Sum of 8 – 11 2 = Sum of 4 – 7 1 = Sum of 1 – 3 0 = Sum of zero
Rank order of vaccine production steps	1 point for each step ranked correctly for a maximum score of 5 on the entire item
Open-ended item about adverse effects	4 point rubric. See the surveys for details.

N.O.V.E.L. Pre Survey

These questions ask for some information about yourself. Please pick the choice that best describes you.

1. Name _____
2. Date _____
3. Age _____
4. What is the last grade you have completed? _____

5. What gender do you primarily identify with?

- ☐ Female (she/her/hers)
- ☐ Male (he/him/his)
- ☐ Non-binary (they/them/theirs)
- ☐ My gender is not listed above.
- ☐ Prefer not to answer

6. What racial/ethnic group do you primarily identify with?

- ☐ Asian/Asian American
- ☐ Black/African American
- ☐ Hispanic American/Latino(a)
- ☐ Native Alaskan
- ☐ Native American
- ☐ Pacific Islander
- ☐ White/Caucasian
- ☐ Mixed: Asian and White
- ☐ Mixed: Black/African American and White
- ☐ Mixed: Hispanic and White
- ☐ Multiracial (or Mixed not listed above)

These questions ask for your opinion. Please pick the choice that best describes what you think. There are no right or wrong answers.

7. How often do you play board games or card games?

- ☐ Never
- ☐ Once a year
- ☐ Once every 6 months
- ☐ Once a month
- ☐ Once a week
- ☐ Everyday

These questions ask for your opinion. Please pick the choice that best describes what you think. There are no right or wrong answers.

8. How important is it for scientists to share resources?

- ☐ Not at all important
- ☐ A little important
- ☐ Somewhat important
- ☐ Moderately important
- ☐ Very important
- ☐ Extremely important

9. How important are these skills in being a good scientist?

	Not at all important	A little important	Somewhat important	Moderately important	Very important	Extremely important
Being a good communicator	☐	☐	☐	☐	☐	☐
Being competitive	☐	☐	☐	☐	☐	☐
Being cooperative	☐	☐	☐	☐	☐	☐
Being independent	☐	☐	☐	☐	☐	☐
Being able to follow the rules	☐	☐	☐	☐	☐	☐
Being creative	☐	☐	☐	☐	☐	☐

10. How important is collaboration between scientists when creating new vaccines?

- ☐ Not important at all
- ☐ A little important
- ☐ Somewhat important
- ☐ Moderately important
- ☐ Very important
- ☐ Extremely important

11. Rate how much you agree or disagree with the following statements.

	Strongly Disagree	Somewhat Disagree	Slightly Disagree	Slightly Agree	Somewhat Agree	Strongly Agree
Human testing of vaccines helps to ensure that new vaccines are safe to use.	☐	☐	☐	☐	☐	☐
Getting vaccinated is a safe way to protect yourself from a disease.	☐	☐	☐	☐	☐	☐
Lots of research goes into developing a vaccine before it is released to the public.	☐	☐	☐	☐	☐	☐
Vaccines contain harmful substances.	☐	☐	☐	☐	☐	☐
I am concerned about the safety of newly developed vaccines.	☐	☐	☐	☐	☐	☐
Healthy people do not need to get vaccinated.	☐	☐	☐	☐	☐	☐

12. If you wanted to find out more information about a new vaccine, where would you go or who would you talk to? Try to be specific in your answer.

Scoring Rubric

Points	Response
0	Blank
1	I don't know, I'm not sure
2	Only inappropriate responses
3	Mixture of both appropriate and inappropriate responses
4	All appropriate responses

Inappropriate Responses	Appropriate Responses
• Google • Nonreliable web sources • Talk to someone who has/had the vaccine • Friends/Peers • Social media • Online forums/Blog posts • Family members/guardians only • Television or movies	• Do my own research ○ From a reliable source ○ Government websites • Talk to a... ○ Vaccine developer ○ Professional ○ Doctor/pediatrician ○ Nurse ○ Health care professional ○ Scientist ○ Pharmacists

Please select the best answer to each question.

13. Scientists are making a vaccine for a new disease. What's the very first question they should try to answer?

- ☐ Should I test my vaccine on animals?
- ☐ How much will the vaccine cost?
- ☐ What will I need to make the vaccine?
- ☐ **What's causing the disease? Correct answer**

14. Which of the following is true about the relationship between pathogens and diseases?

- ☐ Diseases cause new pathogens to appear.
- ☐ There is one type of pathogen that causes most diseases.
- ☐ **Different pathogens cause different diseases. Correct answer**
- ☐ Pathogens do not play a role in causing diseases.

15. Which of the following are types of vaccines? **Select all that apply. Correct vaccine types are bolded.**

- ☐ mRNA
- ☐ live attenuated virus
- ☐ inactivated virus
- ☐ antibiotics
- ☐ viral vector
- ☐ antivirals
- ☐ recombinant protein

16. Which of the following ingredients are typically found in vaccines? **Select all that apply.**
Correct ingredients are bolded.

☐ **pathogen compounds**

☐ vitamins

☐ **preservatives**

☐ **adjuvants**

☐ **culture mediums**

☐ minerals

☐ coagulants

17. **True or False:** Scientists use the same ingredients in the same amounts when creating different vaccines.

☐ True

☐ **False** *Correct answer*

18. Which of the following animal species are commonly used in the testing of vaccines? **Select all that apply.**

Correct species are bolded

☐ nematodes

☐ **mice**

☐ frogs

☐ **hamsters**

☐ **ferrets**

☐ zebrafish

☐ **pigs**

☐ **sheep**

☐ **monkeys**

☐ **baboons**

☐ horses

☐ gorillas

19. Put these steps of the vaccine development process in the order they occur, with #1 being the step that occurs first and #5 being the step that occurs last.

___ 3 ___ A vaccine prototype is tested in humans.

___ 4 ___ The vaccine prototype is approved for production.

___ 2 ___ A vaccine prototype is tested in animals.

___ 1 ___ Scientists adjust the combination of ingredients in a vaccine prototype.

___ 5 ___ The vaccine is distributed to the public.

20. What happens when adverse side effects occur during human testing?

Scoring Rubric

Points	Response
0	Blank
1	I don't know, I'm not sure
2	Only inappropriate responses
3	Mixture of both appropriate and inappropriate responses
4	All appropriate responses

21. Why must vaccines be distributed to the public as quickly as possible?

- ☐ **The disease is still spreading while the vaccine is being produced. *Correct answer***
- ☐ The more quickly the vaccine is produced, the more money can be made.
- ☐ People will riot if the vaccine does not arrive quickly.
- ☐ The vaccine stops working unless it is used quickly.

22. When would scientists begin testing their vaccine prototype in animals?

- ☐ When the vaccine prototype becomes cheap to produce
- ☒ **As soon as they can put together a combination of ingredients *Correct answer***
- ☐ After they find the right ingredients that produce an immune response
- ☐ Before the disease has had a chance to spread

23. In general, how confident do you feel that your answers were correct?

- ☐ Not at all confident (I just guessed)
- ☐ Slightly confident
- ☐ Somewhat confident
- ☐ Moderately confident
- ☐ Very confident
- ☐ Extremely confident

24. How much effort did you put in to answering the questions?

- ☐ No effort at all
- ☐ Very little effort
- ☐ Some effort
- ☐ A moderate amount of effort
- ☐ A lot of effort
- ☐ Maximum effort

N.O.V.E.L. Post-Test

These questions ask for some information about yourself. Please pick the choice that best describes you.

1. Name _____

2. Date _____

3. Age _____

4. What is the last grade you have completed? _____

5. What gender do you primarily identify with?

- ☐ Female (she/her/hers)
- ☐ Male (he/him/his)
- ☐ Non-binary (they/them/theirs)
- ☐ My gender is not listed above.
- ☐ Prefer not to answer

6. What racial/ethnic group do you primarily identify with?

- ☐ Asian/Asian American
- ☐ Black/African American
- ☐ Hispanic American/Latino(a)
- ☐ Native Alaskan
- ☐ Native American
- ☐ Pacific Islander
- ☐ White/Caucasian
- ☐ Mixed: Asian and White
- ☐ Mixed: Black/African American and White
- ☐ Mixed: Hispanic and White
- ☐ Multiracial (or Mixed not listed above)

These questions ask for your opinion. Please pick the choice that best describes what you think. There are no right or wrong answers.

7. How important is it for scientists to share resources?

- ☐ Not at all important
- ☐ A little important
- ☐ Somewhat important
- ☐ Moderately important
- ☐ Very important
- ☐ Extremely important

8. How important are these skills in being a good scientist?

	Not at all important	A little important	Somewhat important	Moderately important	Very important	Extremely important
Being a good communicator	☐	☐	☐	☐	☐	☐
Being competitive	☐	☐	☐	☐	☐	☐
Being cooperative	☐	☐	☐	☐	☐	☐
Being independent	☐	☐	☐	☐	☐	☐
Being able to follow the rules	☐	☐	☐	☐	☐	☐
Being creative	☐	☐	☐	☐	☐	☐

9. How important is collaboration between scientists when creating new vaccines?

- ☐ Not important at all
- ☐ A little important
- ☐ Somewhat important
- ☐ Moderately important
- ☐ Very important
- ☐ Extremely important

10. Rate how much you agree or disagree with the following statements.

	Strongly Disagree	Somewhat Disagree	Slightly Disagree	Slightly Agree	Somewhat Agree	Strongly Agree
Human testing of vaccines helps to ensure that new vaccines are safe to use.	☐	☐	☐	☐	☐	☐
Getting vaccinated is a safe way to protect yourself from a disease.	☐	☐	☐	☐	☐	☐
Lots of research goes into developing a vaccine before it is released to the public.	☐	☐	☐	☐	☐	☐
Vaccines contain harmful substances.	☐	☐	☐	☐	☐	☐
I am concerned about the safety of newly developed vaccines.	☐	☐	☐	☐	☐	☐
Healthy people do not need to get vaccinated.	☐	☐	☐	☐	☐	☐

11. If you wanted to find out more information about a new vaccine, where would you go or who would you talk to? Try to be specific in your answer.

Scoring Rubric

Points	Response
0	Blank
1	I don't know, I'm not sure
2	Only inappropriate responses
3	Mixture of both appropriate and inappropriate responses
4	All appropriate responses

Inappropriate Responses	Appropriate Responses
• Google • Nonreliable web sources • Talk to someone who has/had the vaccine • Friends/Peers • Social media • Online forums/Blog posts • Family members/guardians only • Television or movies	• Do my own research ○ From a reliable source ○ Government websites • Talk to a... ○ Vaccine developer ○ Professional ○ Doctor/pediatrician ○ Nurse ○ Health care professional ○ Scientist ○ Pharmacists

These questions will ask you questions about your experiences playing N.O.V.E.L. Please pick the choice that best describes what you think. There are no right or wrong answers.

12. Did you win your game of N.O.V.E.L.?

- ☐ Yes
- ☐ No
- ☐ I did not get a chance to finish the game.

13. How would you rate your enjoyment of the game, N.O.V.E.L.?

- ☐ It was not fun at all.
- ☐ It was just a little bit fun.
- ☐ It was kind of fun.
- ☐ It was pretty fun.
- ☐ It was very fun.
- ☐ It was totally fun.

14. How important are these skills while playing N.O.V.E.L.?

	Not at all important	A little important	Somewhat important	Moderately important	Very important	Extremely important
Being a good communicator	☐	☐	☐	☐	☐	☐
Being competitive	☐	☐	☐	☐	☐	☐
Being cooperative	☐	☐	☐	☐	☐	☐
Being independent	☐	☐	☐	☐	☐	☐
Being able to follow the rules	☐	☐	☐	☐	☐	☐
Being creative	☐	☐	☐	☐	☐	☐

15. Think about your experiences while playing N.O.V.E.L. How different or the same is the game to how you think vaccines are developed in real life?

- ☐ Totally different
- ☐ Very different
- ☐ A little different
- ☐ Somewhat similar
- ☐ Very similar
- ☐ Exactly the same

16. In your own words, what is one thing you learned from playing N.O.V.E.L.?

17. Is there anything else that you would like to tell us about your experience playing N.O.V.E.L.?

Please select the best answer to each question.

18. Scientists are making a vaccine for a new disease. What's the very first question they should try to answer?

- ☐ Should I test my vaccine on animals?
- ☐ How much will the vaccine cost?
- ☐ What will I need to make the vaccine?
- ☐ **What's causing the disease? *Correct answer***

19. Which of the following is true about the relationship between pathogens and diseases?

- ☐ Diseases cause new pathogens to appear.
- ☐ There is one type of pathogen that causes most diseases.
- ☐ **Different pathogens cause different diseases. *Correct answer***
- ☐ Pathogens do not play a role in causing diseases.

20. Which of the following are types of vaccines? **Select all that apply.**
Correct types are bolded

- ☐ mRNA
- ☐ live attenuated virus
- ☐ inactivated virus
- ☐ antibiotics
- ☐ viral vector
- ☐ antivirals
- ☐ recombinant protein

21. Which of the following ingredients are typically found in vaccines? **Select all that apply.**
Correct ingredients are bolded

- ☐ pathogen compounds
- ☐ vitamins
- ☐ preservatives
- ☐ adjuvants
- ☐ culture mediums
- ☐ minerals
- ☐ coagulants

22. **True or False:** Scientists use the same ingredients in the same amounts when creating different vaccines.

☐ True

☐ **False** *Correct answer*

23. Which of the following animal species are commonly used in the testing of vaccines? **Select all that apply.**

Correct species are bolded

☐ nematodes

☐ **mice**

☐ frogs

☐ **hamsters**

☐ **ferrets**

☐ zebrafish

☐ **pigs**

☐ **sheep**

☐ **monkeys**

☐ **baboons**

☐ horses

☐ gorillas

24. Put these steps of the vaccine development process in the order they occur, with #1 being the step that occurs first and #5 being the step that occurs last.

- ___3___ A vaccine prototype is tested in humans.
- ___4___ The vaccine prototype is approved for production.
- ___2___ A vaccine prototype is tested in animals.
- ___1___ Scientists adjust the combination of ingredients in a vaccine prototype.
- ___5___ The vaccine is distributed to the public.

25. What happens when adverse side effects occur during human testing?

Scoring Rubric

Points	Response
0	Blank
1	I don't know, I'm not sure
2	Only inappropriate responses
3	Mixture of both appropriate and inappropriate responses
4	All appropriate responses

Inappropriate Responses	Appropriate Responses
• People get sick/die • The vaccine is approved anyway • The scientists will just use a different already available vaccine for human testing • All participants get sick	• Scientists figure out what caused the side effects • Ingredients are adjusted • The vaccine will not be given to humans • The scientists will return to animal testing

26. Why must vaccines be distributed to the public as quickly as possible?

- ☐ **The disease is still spreading while the vaccine is being produced. *Correct answer***
- ☐ The more quickly the vaccine is produced, the more money can be made.
- ☐ People will riot if the vaccine does not arrive quickly.
- ☐ The vaccine stops working unless it is used quickly.

27. When would scientists begin testing their vaccine prototype in animals?

- ☐ When the vaccine prototype becomes cheap to produce
- ☐ **As soon as they can put together a combination of ingredients *Correct answer***
- ☐ After they find the right ingredients that produce an immune response
- ☐ Before the disease has had a chance to spread

28. In general, how confident do you feel that your answers were correct?

- ☐ Not at all confident (I just guessed)
- ☐ Slightly confident
- ☐ Somewhat confident
- ☐ Moderately confident
- ☐ Very confident
- ☐ Extremely confident

29. How much effort did you put in to answering the questions?

- ☐ No effort at all
- ☐ Very little effort
- ☐ Some effort
- ☐ A moderate amount of effort
- ☐ A lot of effort
- ☐ Maximum effort

Teacher Interview Protocol

1. Can you describe your students who participated in this study?
2. Can you describe the setting of how N.O.V.E.L. was used? (Indoor vs. Outdoor, Group size, Noise level, time of day, energy level of students)
3. On a scale of 1-10 how would you rate student engagement with the game?
4. What did you feel were some of the strengths of N.O.V.E.L.?
5. Did you encounter any problems while using N.O.V.E.L.? What were they?
6. Were there any unique scenarios or situations you observed that you would like to share with the researchers?
7. If you could change anything about N.O.V.E.L. what would it be?
8. Would you consider using N.O.V.E.L. again? Why or why not? What factors would influence your decision?
9. Is there anything else you would like to tell me that you didn't already get a chance to share?