Critical Thinking Goes V.I.R.A.L.: Free Downloadable Virus Transmission Activity

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ABSTRACT

In this manuscript, we share a free, downloadable activity to teach viral transmission, efficacy of vaccination, and the value of safety compliance measures. It takes approximately 30–40 minutes to conduct following a 5-minute introduction. Additional discussion / out-of-class-assignment time can be varied and adapted to meet the level and time of classes. Sophomore pharmacy majors taking an anatomy and physiology class and junior and senior biology / molecular biology majors taking virology or immunology classes were given a set of questions to assess their comprehension of risk factors for COVID-19 and vaccine prioritization before conducting the activity and after performing the activity. In general, 33% of the time, all groups of students correctly identified the appropriate order of factors assessed according to their impact on COVID-19 risk. Juniors and seniors had markedly greater depth of understanding as a result of completing the activity. While sophomore improvement was less impressive, the sophomores improved their understanding of all addressed complicating factors for COVID-19 infection. Students were also asked to rate the activity for fun and learning effectiveness: 73% of sophomore students and 79% of junior and senior students graded the activity an A or a B for fun, and 74% of sophomore students and 90% of junior and senior students gave the activity an A or B for helping them to understand viral transmission.

Key Words: viral transmission; risk factor; free A&P activity; quantitative analysis; critical thinking; graphing.

Introduction (V.I.R.A.L.: Viral Infection Risk Assessment Lab)

Finding engaging laboratory exercises to complement the immune system chapter of most anatomy and physiology and microbiology classes is a challenge. These are especially complex topics to teach at an introductory level and often require pricey reagents and special safety measures. By approaching these lab topics from the perspective of preventing disease transmission, instructors can often avoid such problems.

Simplistic exercises involving the transfer of fluorescent dye by handshaking (MacPhee, n.d.; Schwingel, 2018) and exchange of cards (Wiles, 2015) or candy (Williams, 2011) are fun activities to demonstrate transmission of simulated infection. However, they require students to participate in physical contact that may actually expose them to microbial contaminants. In 2015, Nicola Barber and Louisa Stark reviewed online resources for teaching about the spread of infectious diseases. They found resources geared toward middle school, high school, and undergraduate students that were limited in scope and did not include transmission risk factors. Additionally, student interaction was with websites rather than classmates, and most required students to be in the same room.

Due to recent events, viral transmission is likely to be included in more curricula. During the COVID-19 pandemic, and any year in which the flu is bad, student contact via handshaking or touching common items is discouraged. Consequently, there is a growing need to convert these activities into remote exercises to effectively teach viral transmission modes while optimizing student/teacher safety. With the rise in online learning, this interactive exercise promotes individual and collaborative critical thinking.

The COVID-19 pandemic inspired us to devise this laboratory activity. We used it with a large anatomy and physiology class for sophomore pharmacy majors (N = 122) and with immunology and virology classes for junior and senior biology / molecular biology majors (N = 18), and we are confident that it could be tweaked by the instructor for use in high school biology classes. For lower level students, analysis might need to be a whole class rather than individual activity due to relative competence with using Excel.

Significant benefits of this exercise are its game-like format that actively engages students, its flexibility to deliver content face to face or remotely, and its implementation at no cost. Multiple opportunities are provided for students to collect data, plot results, and analyze outcomes. The questions provided for instructors will promote class discussions to critically assess a variety of scientific concepts. As time allows, discussions could be expanded into other important social considerations, such as “why are communities of color disproportionately impacted by COVID-19?”

In general, connecting an active learning exercise with real-world application has been demonstrated to facilitate long-term...
knowledge retention (Young and Anderson, 2010). Junior and senior biology / molecular biology majors and sophomore pharmacy majors at our small, four-year private college rated this active-learning exercise as fun, clear, and helpful in improving their understanding (see results). All five instructors involved found the activity easy to administer. For these reasons, we want to share this viral transmission activity (V.I.R.A.L.) with you in this venue. With minimal instructor preparation time and for no cost, we believe V.I.R.A.L. may help you safely and effectively enhance your students’ knowledge and retention of critical viral transmission risk factors and how they impact the infection trends they see daily.

**Specifics of Activity Design**

To use this activity, download the Excel spreadsheet available with the online version of this article. To develop this exercise, the authors had assistance from a faculty member who taught basic computer courses, including how to use Excel (see acknowledgements). Additionally, some websites easily accessed on the internet were used (Ablebits.com and free online Excel training found at TrumpExcel.com).

This spreadsheet is designed using multiple random item formulas to assign students to groups with corresponding risks for contracting COVID-19. Each parameter is associated with risk values, which are designated in columns AW–BT. The formulas in Row 2 are standard Excel formulas used to randomly populate the spreadsheet based on the risk factors set in columns AW–BT, which correspond to relative risk of severe infection/death due to each variable. Column L is the sum of the risk factors. Thus, these factors assign a numerical value to risk, which is used as a multiplier to assign total COVID-19 risk. The values used are derived from the sources indicated in Table 1. The next columns in the spreadsheet allow students to examine safe distancing/masking compliance (Column M—always compliant, sometimes compliant, never compliant). Then Column P randomly assigns students a 50% chance of exposure to SARS-CoV-2 (yes = 1 as a multiplier and no = 0 as a multiplier).

The spreadsheet then generates a health status ranging from unexposed/uninfected through asymptomatic, mild case, and severe case (Column S) and a survival or death status (Column T). Column U is blacked out and left intentionally blank. The next group of columns (orange) allow students to explore the effect of vaccination on survival. Column V is the vaccine eligibility of the person (Ohio Department of Health, n.d.), and Column Y is whether or not the individual chooses to be vaccinated. Columns AA and AB are COVID-19 status and survival following vaccine, if taken. Column AC is blacked out and left intentionally blank.

The last set of student-use columns (blue) allow students to consider risky behavior, such as attending a super-spreader event, where Column AD is event attendance and Column AF is viral exposure. Columns AI and AJ are COVID-19 status and survival following a super-spreader event. Column AK allows students to compare the efficacy of vaccination in light of a super-spreader event, where Columns AN and AO represent survival based on whether or not the person was vaccinated before attending the event. Columns AW–BT are risk factor parameters paired with their relative risk, used to determine COVID-19 status and survival under the various conditions.

For all Columns B–AU, the parameters are listed in the top row and the formulas are in the second row. Columns AV–BT are risk settings and may be altered as desired by the teacher prior to the activity, but they should not be modified during the activity. Modifications are easily made; for example, column BE lists jobs and column BF lists risk factors associated with those jobs—teachers could modify the jobs, the assigned risk, or both.

**Instructions**

Students enter their names in the first column starting with A3. Once all names have been entered (you can enter each student more than once if you want a larger data set), the second row should be highlighted from Columns A—AS and then the left bottom corner should be used to drag down, generating a data set. **NOTE:** The way V.I.R.A.L. is set up with random generation, every click will cause all columns to reset. Thus, as soon as a data set is generated, Columns A–AS should be copied to a separate sheet for data analysis, and the second row should immediately be deleted on that sheet. Now the data will remain unchanged during analysis.

### Table 1. Risk factors used in this activity to predict COVID-19 infection.

| Column | Risk Factor | Elucidation of Risk Factor | Sources Used to Assign Risk Factors |
|--------|-------------|----------------------------|------------------------------------|
| B      | age         | age groups reflect CDC designations for disease risk for severe COVID-19 infection | CDC, 2021a  
CDC, 2021c |
| D      | health status | healthy or 1 of 10 disorders identified by the CDC that increase risk of severe COVID-19 infection | CDC, 2021b |
| F      | location     | rural, suburban & inner city reflect population density risk | CDC, 2020  
Matheson, 2020 |
| H      | economic status | poor, middle class & rich reflect access to health care | Patel, 2020 |
| J      | job          | 30 occupations from rock star to bus driver | Lu, 2020 |
○ Data Analysis

Now students can be asked to assess the influence of age, health, socioeconomic status, living location, and job risk on COVID-19 survival. For each of these, first have students highlight Column P, “SARS COV2 Exposure” (see Figure 1A), and sort that column by clicking on A–Z sort (see Figure 1B), making sure they click on Expand Selection for each sort (see Figure 1C).

![Figure 1A](image1.png)
![Figure 1B](image2.png)
![Figure 1C](image3.png)

**Figure 1.** Data analysis using Excel. (A) Column P, highlighted; (B) Sort function; (C) “Expand the selection” option.

Those who are randomly unexposed will be uninfected (see Figure 2, Step 1, “no” circled). Step 2 is to “insert a line” between uninfected students and infected counterparts (“yes” in rectangle). Those who are exposed to SARS-CoV-2 can be sorted by age, health, location, etc. In this example, they are sorted by wealth class (brackets); again, have students select Expand Selection. After all desired sorting is complete, insert lines between groups. Then within each group, the COVID-19 status can be sorted. We strongly recommend you encourage your students to color code their data to improve organization and readily indicate important differences.

Students can then similarly assess the value of vaccination and the attendance at a super-spreader event, both vaccinated and unvaccinated. Remember that all data sets must first be sorted for whether or not the person was exposed to the virus—for this activity the likelihood of being exposed is always 50%, based on random generation. It can be reset if the instructor so desires.

Now students can use their graphed data to compare relative effects. Figure 3 shows an example for an individual student who has effectively demonstrated that, in this particular use of the activity, economic status plays a greater role in survival than age (see Figure 3). During a future session of the activity, a student might obtain results that indicate the reverse—the random generator function in the game design ensures an element of surprise. Of course, risks are assigned based on real-world information (see Table 1), so it is unlikely that results will contradict what is commonly known, that vaccination prevents disease.

![Figure 3](image4.png)

**Figure 3.** Example data graphed to show how activity V.I.R.A.L. can be used to demonstrate the impact of specific parameters on the likelihood of COVID-19 infection.

○ Worksheets/ Assessment Tools

Students can now answer the following questions by completing these step-by-step instructions to finish their analysis.

**Question 1**

A. Graph the impact of safe masking and distancing practices. First sort whether or not they mask; then sort COVID-19 status; and finally sort survival. Your graph should have three columns: masked always / masked sometimes / never masked. Columns should have bar fragments for uninfected people (unexposed—this will be about half, based on random numbers generated by the program); asymptomatic cases, mild cases, severe cases, and survival.

B. Based on your data, does it help to wear the mask sometimes? For example:

“For severity of COVID-19, the people who sometimes wore the mask compared to the noncompliant had a
dramatic difference. In the “sometimes” category, about 13% had severe cases of COVID-19 while close to 40% had a severe case in the noncompliant category. Based on the percentages of fatal, severe, mild, and asymptomatic cases, we can conclude that wearing a mask occasionally, over not at all, can improve the chance of survival. However, wearing a mask all the time is the best option because those people experienced no deaths or severe cases.”—an immunology student.

C. Think about modes of transmission. How would the spread of a disease differ if the pathogen is airborne, foodborne, or waterborne or if it requires physical contact, like a handshake?

**Question 2**

A. Graph the impact of vaccine access on infection rate. First sort by whether or not they choose to get vaccinated—because it doesn’t matter when you are eligible if you choose not to. Next, sort by vaccine eligibility time. Your graph should have six columns – vaccinated 1st round, 2nd round, 3rd round, 4th round, 5th round, and unvaccinated. Each column should have bar fragments for uninfected people (unexposed—this will be about half, based on random numbers generated by the program), asymptomatic cases, mild cases, severe cases, and survival.

B. Based on your data, how does getting vaccinated affect survival rate?

C. Based on your data, does it matter when you get vaccinated?

D. Why does getting vaccinated protect people who are too young or otherwise unable to get vaccinated? For example: “If more people are vaccinated, there will be less people who are infected with SARS-CoV-2. As a result, there would be less people who are carrying and spreading the virus. This idea of herd immunity will decrease the ability for SARS-CoV-2 to be transmitted easily and will in turn protect the people who are too young or otherwise unable to get the vaccine.”—an anatomy and physiology student.

**Question 3**

A. Graph the impact of attending a super-spreader event. First copy the whether-they-attended column (Column Q) and paste in front of the vaccinated-before-super-spreader column (Column U). Now put a space in front of the second copy of Column Q. Sort the first set of numbers by whether they attended (Column Q) and then sort the attendees versus the nonattendees for COVID-19 status and survival. Then, looking at the second set of numbers, separate out those who were vaccinated before the event from those who were not, and compare the COVID-19 status for these two groups.

B. Based on your data, how did attending a super-spreader event impact COVID-19 status and survival?

C. Based on your data did it make a difference if you were vaccinated before attending the super-spreader event? For example: “Those who were vaccinated only experienced asymptomatic infections. Those who were unvaccinated were more likely to experience severe symptoms and death. Those who attended the event and were unvaccinated had a high chance of death.”—a virology student.

**Question 4**

A. Choose one additional risk factor and graph the COVID-19 status and survival rate for job exposure risk, health status, age, or geographical location.

B. Based on your data, what is the importance of that risk factor?

C. What other factors affect our likelihood of getting sick from SARS-CoV-2?

D. Which factors impacting SARS-CoV-2 infection can we control? Which can we not control?

**Discussion**

Following completion of the activity, class discussion of the results might include any of the questions posed previously or the additional following points:

- What is the impact of isolation on the spread of infection for (A) people who have COVID-19, (B) people who have not been infected, and (C) people who have been exposed but are asymptomatic?

- Many diseases, such as the common cold, don’t have visible symptoms during their most infectious stage. Why? What would happen if they did?

- Considering the reduced number of reported influenza and RSV (respiratory syncytial virus) cases during the COVID-19 pandemic, how could what we have learned about masking and distancing be applied in the future?

**Assessment of Activity Effectiveness**

The V.I.R.A.L. activity was administered to sophomore pharmacy majors in an anatomy and physiology class (N = 122) and to junior and senior biology / molecular biology majors taking virology or immunology classes (N = 18). To assess teaching effectiveness, students were first asked to rate, on a relative basis, the impact of several factors associated with SARS-CoV-2 infection (age, health, income, location population density) and the relative importance of specific factors (age and various health conditions) on whom should be vaccinated first. They repeated this rating immediately after completing the activity and then again after finishing data analysis. In general, all groups of tested students correctly identified the appropriate order of impact on COVID-19 risk 35% of the time—we did not analyze how far off their evaluation was (e.g., did they choose 3 versus 4 or 1 versus 5). It should be noted that junior and senior biology majors did not perform significantly differently from sophomore pharmacy majors. It is unclear whether this apparent lack of significant difference in performance is a legitimate estimate of initial understanding or a vagary of smaller numbers of biology students. Students were asked to again evaluate the relative risk of these factors after completing the activity. The percentage of students who showed improved understanding of parameters affecting viral transmission is shown in Figure 4. Juniors and seniors had markedly greater depth of understanding as a result of completing the activity; however, for all parameters, post activity, even the
sophomores improved their understanding of all addressed complicating factors for COVID-19 infection.

Next, students rated the activity for fun and educational value using an A-F grading scale. Of junior and senior students, 79% graded the activity for fun as an A or a B, compared to 73% of freshman and sophomore students. Importantly, 74% of freshman and sophomore students and 90% of junior and senior students gave the activity an A or B for helping them to understand viral transmission.

**Conclusion**

VI.R.A.L., a computer-aided virus transmission laboratory activity, is a highly effective and enjoyable method for teaching undergraduates the factors affecting viral transmission and infection severity. We feel that this activity could be easily adapted for use at the high school level as well. Many of these students are entering healthcare careers, and the issues explored in this activity are germane to their future professional lives.

In the process of completing the activity, and in the graphing and analysis that follow it, students gain a stronger understanding of how viruses, such as SARS-CoV-2, are spread and how they differentially affect people based on factors such as age, preexisting health conditions, employment, living conditions, compliance with public-health advice, vaccination, and attendance at public events.

Analysis includes several questions that encourage critical thinking and discussion that can be modified or augmented at the instructor’s discretion.

The activity relies on a preset Excel spreadsheet, and detailed instructions for the activity are provided within this paper. There is no cost and very little preparation time. It would work well in conjunction with short laboratories or where students are waiting for results of other experiments. Of course, the activity is ideal when students are not able to gather in person but are synchronously online, or it could be adapted to present asynchronously.

In conclusion, VI.R.A.L. is an effective and inexpensive method for teaching key concepts of viral transmission and fatality. Students find VI.R.A.L. interesting and show increased understanding after completion.

**Acknowledgements**

The authors would like to express their heartfelt gratitude to Dr. Michael Kolotila, Northern Essex Community College, Haverhill, MA, for his expertise and patience in explaining how to use Excel formulas.

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