Scenario-Based Health Risk Analysis of Re-Opening Elementary Schools in Upstate SC during the COVID-19 Pandemic

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Executive Summary

The purpose of this study is to perform a scenario-based health risk analysis of re-opening elementary schools in Spartanburg County during the COVID-19 pandemic. By creating a basic model of an elementary school in Python, we were able to simulate the spread of COVID-19 in the 39 elementary schools in Spartanburg County during the Fall 2020 semester. Three scenarios were created, each with a different set of safety precautions put in place to combat the spread of the virus. The No Precautions scenario involved no changes to school policy, with students facing potential exposure in the lunchroom and at assemblies as well as in the classroom. The Minor Precautions scenario limited exposure by canceling assemblies and hosting lunch in the individual classrooms; furthermore, social distancing practices were put in place, and any time an individual displayed COVID-19 symptoms, all students and teachers within that classroom were tested. The Moderate Precautions scenario retained the policies established in the Minor Precautions scenario as well as the implementation of a policy requiring surgical masks to be worn at all times. Testing was expanded to include everyone in the school when an individual began displaying COVID-19 symptoms.

The simulation was run 20 times, and those results were aggregated and analyzed via R and Tableau. A median 1,242 COVID-19 infections originated in the No Precautions scenario, more than three times more than the 384 cases in the Mild Precautions scenario and over five times more than the 219 cases in the Moderate Precautions scenario. In the No Precautions scenario, over 90% of cases were defined as "Secondary". Secondary cases originated within the scope of the school; that was drastically reduced to less than 50% of cases in the Moderate Precautions scenario, implying that the risk of contracting COVID-19 in school was less than the risk of contracting it from another source. We conclude that a blend of the Minor and Moderate Precautions scenarios best suits most elementary schools; implementing social distancing practices and requiring surgical masks reduces the spread of COVID-19, as does removing the potential of exposure in the lunchroom or at assemblies. PCR testing upon the discovery of a COVID-19 positive individual is recommended but may be too costly to do at the school level; instead, we recommend those with the most significant opportunity for exposure (generally those in the same classroom) be tested.

Introduction

COVID-19, widely known as coronavirus, is a deadly virus that has swept the world into a pandemic storm. According to Hopkin's Medicine, the pandemic originally began towards the end of 2019. This specific virus is a large family of single-stranded, positive-sense RNA viruses that are circulating among mammals. The name 'coronavirus' is derived from the image in the electron microscopic image resembles a crown (CDC, 2020). Six specific strains have infected humans, which are derived from the common cold (CDC, 2020). According to John Hopkin's Medicine, coronavirus is a mutation of the severe acute respiratory syndrome, SARS, which spread in several countries in Southeast Asia, North America, among others. According to SC DHEC, globally,

there are 13,280,066 confirmed cases, and in just South Carolina alone, there are 67,612 total confirmed cases as of July 19, 2020. Transmission occurs through person-to-person interaction via droplets usually produced by coughing or sneezing. To combat the spread, the United States has implemented significant lockdown measures including the closure of schools.

Currently, more than 50 million children are utilizing online learning while re-opening schools for in-class learning is still up for debate due to continuous surges in the number of people infected (CDC, 2020). In high transmission areas, protective measures have been put in place such as face masks, social distancing, and disinfecting. Compared with adults, children are 3-fold less susceptible to contracting COVID-19, and those who do are more likely to be asymptomatic (CDC, 2020). In a John Hopkins Medicine recent study, 90% of children who tested positive had mild symptoms or were asymptomatic carriers.

As the fall semester is approaching, schools are wrestling with the idea of re-opening classrooms and risks associated with that decision. However, schools are essentially promoting behaviors that limit the transmission of COVID-19 in classroom activities. The three different categories of re-opening educational facilities are low spread, medium spread, and highest spread (CDC, 2020).

Background

"The coronavirus disease 2019 (COVID-19) outbreak is induced by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)" (Viner). The outbreak was declared to be a pandemic on March 12, 2020 by the World Health Organization. On March 18, 2020, South Carolina closed all schools to reduce the spread of the Covid-19 virus. On April 7, a "work or home" order was issued for Spartanburg county, closing non-essential businesses and requiring individuals to remain at home outside of necessary travel. At the time, most students were out of school for spring break

but were told not to return as the country witnessed the number of cases rise. Teachers were forced to change their classroom lesson plans to an online platform in a matter of weeks. Communication with parents was limited to email, phone calls, or online meetings. Some teachers allowed parents to pick up packets that included activities to keep the students engaged and on track with learning.

As the fall semester approaches, school officials struggle with finding ways to re-open schools. The main precautions that have been suggested by the Center for Disease Control and Prevention (CDC) have included social distancing, wearing a mask or face covering, and washing hands/surfaces. Research shows that young children are less likely to die from contracting the virus. Between February 1, 2020 and July 4, 2020, according to the CDC, there have been a total of 6 deaths in the United States of children between the ages of 1-4 and 14 total deaths for children between the age of 5-14. (CDC, 2020) Children who contract COVID-19 are typically asymptomatic throughout the infection, making detection and prevention of further spread much more difficult. (CDC, 2020) This could pose a threat to elementary schools who plan to open in the fall because without testing; it is hard to tell what students may have contracted the virus. School officials and parents need to be aware of whether preventative measures make a difference in protecting students as they return to school.

Method

The first cohort of the Business Analytic students at the University of South Carolina Upstate, decided to focus on the impact of the Covid-19 virus on elementary schools in the Upstate for their capstone project. The research includes visualizations and a model that illustrates the possible outcomes of returning elementary school students and teachers to the classroom. Three levels of risk are modeled in the scenario-based simulation. The model represents the population of

elementary schools in Spartanburg, South Carolina. In scenario one, students return to school with no significant implantations or changes. The second scenario moderate implementations include social distancing and refraining from holding lunch in a cafeteria. School assemblies will also be canceled to limit the chance of exposure to teachers and students. The third scenario will include all the implementations in scenario two. In addition, the students will be required to wear a face mask to lessen the jeopardy of spreading the virus. The goal of this project is to analyze the effectiveness of some precautions that have been suggested by the CDC in an elementary school environment.

Switching from the traditional classroom environment to remote learning was difficult for parents, teachers, and students. Based on a study conducted by Brown Center Chalkboard, the gap between high and low achieving students is continuously increasing with the limited adaptability of online learning. Teachers have researched previous test scores to compare the learning curves of students due to online learning. Based on a national sample of 5 million students in grades 3rd to 8th who took MAP growth assessments, a comparison of the growth of students who completed a standard school year with face to face instruction was analyzed vs. students exposed to different online scenarios. (Soland et al., 2020) To stay connected to students, teachers relied on calling students and holding virtual meetings with them online. Those who live in rural areas have had difficulty with internet connectivity and internet access. An article from Edutopia.org mentioned that internet "connectivity remains a pervasive equity issue" as well. (Fleming, 2020) Another equity issue for superintendents to consider would be the children who depend on school meals. Many schools in Spartanburg County have been providing meals for the students during the semester. Pauline Glenn Springs Elementary delivered meals to students three times a week by using by bus. Other schools provided pickup times for parents to come and collect meals for their homes.

Concern has also been raised regarding social development for elementary-aged students in a virtual-only environment. According to the American Academy of Pediatrics, while attending elementary school, children can socially develop and interact with other children. This is a critical age since personalities and friendships are formed. When they start attending school, children spend much of the day with other children and away from their parents. Now that schools are closed, there is a concern that children may be missing out on the opportunity to interact with other children and get used to being away from home. (medlineplus, 2020)

The adverse effects of schools closing have been listed above; however, some students are thriving from the experience of remote learning. Remote learning has offered students the ability to create their schedules if they complete the work by the given deadline. While attending school, students typically have inflexible schedules that do not work well for all students. (Fleming, 2020) "Research has found jam-packed schedules can be a significant challenge for a child to juggle" (Fleming, 2020). Anxiety may develop in students who feel obligated to follow a strict class schedule. Students who have behavioral and social issues while attending school are benefitting from online learning as well. Students who are shy and hyperactive can focus when they are not distracted by others in a classroom environment.

Statement of Work

The purpose of this project is to analyze the health risks associated with re-opening elementary schools in the Upstate to students, faculty, and families of students. Potential scenarios are presented to determine what time frame elementary schools could potentially re-open.

Key objectives of this project

1. Assess health risk in a data-driven manner

2. Establish specific scenarios in which elementary schools could re-open

3. Forecast health risk in each simulated scenario in which elementary schools could re-open

Major deliverables

1. Research paper

2. Online presentation

3. Data visualizations

4. Predictive model

Key Milestones

1. Determine project scope

2. Identify key data sources

3. Establish specific scenarios for potential school re-opening

4. Determine how to measure health risk properly

5. Create a predictive model for measuring health risk

6. Apply the model to each scenario and analyze results

Identify Major Constraints

1. Data on re-opening of schools during the COVID-19 pandemic is scarce

2. There is no modern precedent for closing schools in the US due to a widespread pandemic

Scope Exclusions

1. Detailed analysis on COVID-19 and how it affects the individual
2. Non-elementary schools
3. Predictive modeling on the effect of school closure on elementary students

Statistical Modelling

Several variables in our predictive model (also referred to as the "simulation") were sourced from external datasets. The following explains where this data was retrieved from, the calculations used to transform them into usable values, and the context of this data within our simulation.

- DAILY_EXT_ODDS: Odds of a given person on a given day contracting COVID-19 outside of school (I.e. outside the scope of the simulation)
    - 2491 cases in Spartanburg County since the Stay-at-home order was lifted (SCDHEC, 2020)
        - Note: A 5-day buffer was used to account for the average incubation period
    - Data collected from May 9th-July 16th - a span of 67 days
    - Estimated 2% of all COVID-19 cases are elementary school-aged children (California Dept. of Public Health, 2020)
    - Estimated 82% of all COVID-19 cases are between ages 21-80 (teacher aged) (California Dept. of Public Health, 2020)

    - We estimate (2491/67) * 0.02 = 0.74 new cases per day in elementary-aged children and (2491/67) * 0.82 = 30.34 new cases per day in adults ages 21-80
    - 71% of Spartanburg County is between ages 21-80 (Census Reporter, 2019)
    - The total population of Spartanburg County is estimated at 313,888 (Census Reporter, 2019)
    - 313,888 * 0.71 = 222,861 individuals between ages 21-80
    - Our sample included 1,526 teachers (222,861 /1,526 = 146.04)
    - We can expect 30.34/146.04 = 0.2077 new cases per day in our teacher population
    - The student population is 9408, so 0.74/9408 = 0.007866% chance of a given student on a given day contracting COVID-19 outside of our scope
    - Teacher population is 1526, so 0.2077/1526 = 0.01361% chance of a given teacher on a given day contracting COVID-19 outside of our scope
- HEAVY_EXPOSURE_ODDS: Odds that an individual will contract COVID-19 based on a single instance of close contact with an individual who is currently capable of transmitting COVID-19
    - According to a study done by Dr. Zunyou Wu, the chief epidemiologist of the Chinese CDC in Beijing, the transmission rate of COVID-19 between individuals with close contact was 1%-5% in a sample of 38,000 people (Alexander Otto, M., 2020)
    - An average of 3.5% was used for our simulation – this was the value used for our No Precautions scenario

    - According to research out of Harvard's T.H. Chan School of Public Health, Social Distancing practices can lessen COVID-19 transmission by an estimated 60% (Kissler, S., et al., 2020)
    - 0.035 * (1-0.6) = 1.4% - this is the value used in our Minor Precautions scenario
    - According to research out of the Aerosol Science and Technology Journal, surgical masks lessen the rate of particle spread at approximately 60% (He, X., et al., 2013)
    - 0.035 * (1-0.6) * (1-0.6) = 0.56% - this is the value used in our Moderate Precautions scenario
- SEVERITY_WEIGHTS: The likelihood of suffering a given level of severity of COVID-19 infection based on age range (CDC, 2020)
    - Possibilities were [Mild, Hospitalized, ICU, Fatal]
    - Ages 0-19: [97.95%, 2.05%, 0%, 0%]
    - Ages 20-44: [79.2%, 17.55%, 3.1%, 0.15%]
    - Ages 45-54: [66.69%, 24.75%, 7.9%, 0.65%]
    - Ages 55-64: [64. 75%, 25.3%, 7.95%, 2%]
    - Ages 65-74: [46.7%, 36.05%, 13.45%, 3.8%]
- AGE_RANGE_WEIGHTS: The odds of a given teacher falling into a certain age range (US Department of Education, 2009)
    - Ages 20-44: 60%
    - Ages 45-54: 21.2%
    - Ages 55-74: 18.8%
- INFECTION_LENGTH: Number of days until case is resolved

    - Most COVID-19 cases resolve within 7-10 days (CDC, 2020)
- ASYMPTOMATIC_LENGTH: Number of days until symptoms develop
    - Most patients develop symptoms within 5-6 days (Healthline, 2020)
    - ODDS_ASYMPTOMATIC_TEACH: Odds that a given COVID-19 positive teacher has an asymptomatic infection
        - According to a study on the Diamond Princess cruise ship, an estimated 17.9% of COVID-19 infections are asymptomatic infections (Mizumoto, K., et al., 2020)
    - ODDS_ASYMPTOMATIC_STUD: Odds that a given COVID-19 positive student has an asymptomatic infection
        - According to a study on children in Zhejiang, China, an estimated 28% of children become asymptomatic carriers (Qui, H., et al., 2020)
    - These are significant figures in our simulation, as an asymptomatic carrier exposes close to twice as many individuals as symptomatic carriers

Though our final simulation featured three distinct scenarios with varying levels of precautions, each scenario is a modified version of our original default scenario. The logic of this scenario is laid out in Figure 4.2.1, which lays out the potential logical paths a given individual can take on a given day. In this default scenario, healthy students and teachers have a chance of contracting COVID-19 in the time between school days from an individual outside of the scope of our project (I.e. outside of school) based on the DAILY_EXT_ODDS variable discussed in 4.1. Once in school, any healthy student or teacher in a classroom with an infected individual who has not yet developed symptoms is considered "exposed," and has a chance of contracting

COVID-19 from the infected individual. This risk is determined by the HEAVY_EXPOSURE_ODDS variable discussed in 4.1.

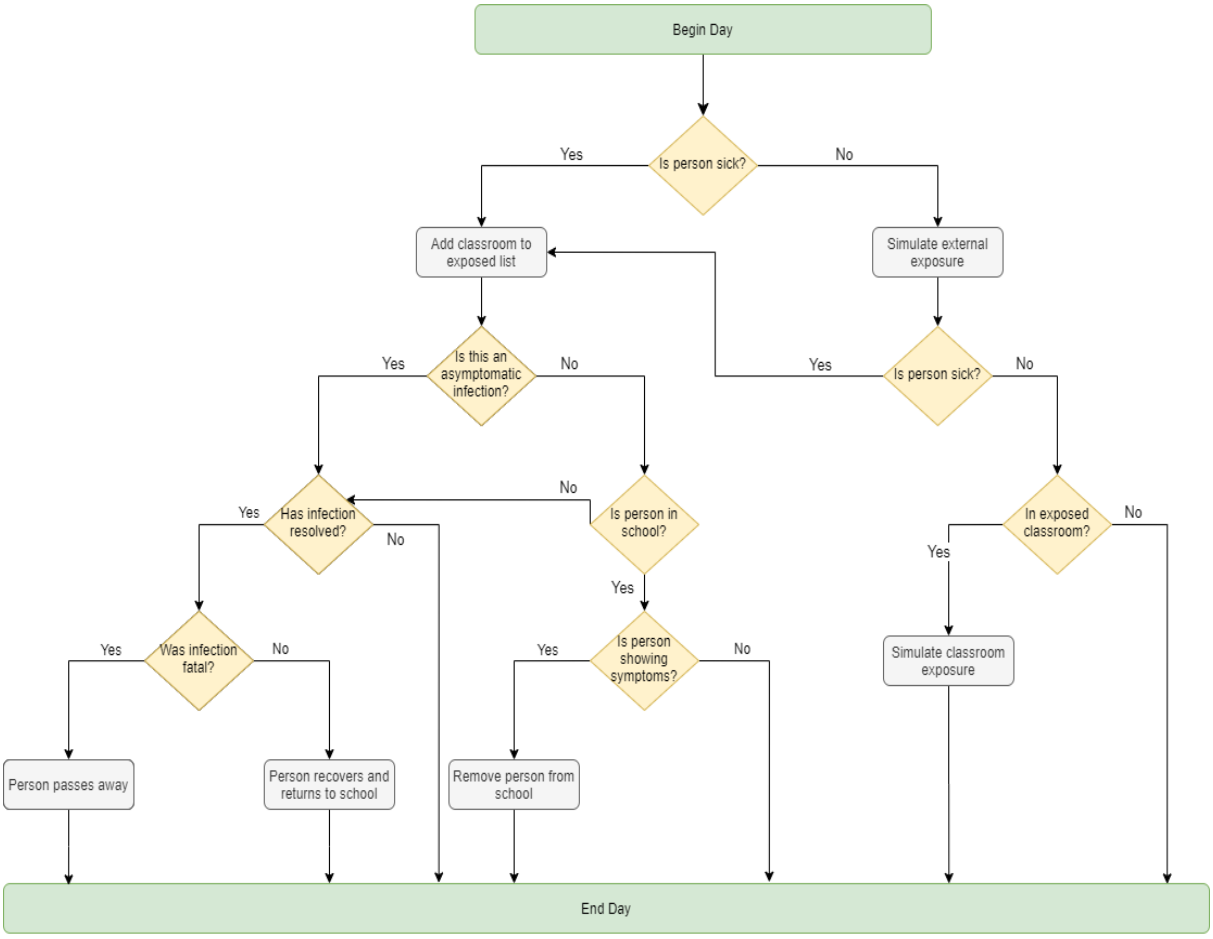

Figure 4.2.1

For infected individuals, we do not consider any transmission to healthy individuals outside of the scope of the elementary school; only those in the classroom are exposed to the infected individual in our default model. One note to make is that individuals in our simulation are considered to be capable of transmitting the COVID-19 virus instantly upon infection; in reality, there is some time that elapses between an individual's exposure to the virus and the individual's ability to transmit the virus to others. Another important note is the existence of "asymptomatic carriers" in our simulation (also referred to as "asymptomatic infections"), or individuals who are infected with COVID-19 and are capable of transmitting the virus to others, but do not develop

symptoms at any point during the infection. In most cases, this individual will not know he or she ever had COVID-19 unless an antibody test is later administered. (Beeching, N., 2020) In our simulation, the proportion of COVID-19 cases that are asymptomatic infections is a critical factor in how many cases will eventually develop. Asymptomatic carriers will on average expose 1.5-2x as many healthy individuals as those who eventually develop symptoms. If an individual is a "symptomatic carrier," we determine whether they are now displaying symptoms, and if so, we temporarily remove them from school. If the individual has an asymptomatic infection or is not yet showing symptoms, we determine whether the infection has resolved. In the case of fatal infections, this results in the individual passing away and being permanently removed from the simulation. In non-fatal infections, the individual recovers from COVID-19. The recovered individual is marked as "healthy" in the simulation and returns to school.

Not shown in the flowchart is the process of "infecting" an individual in the simulation. When healthy individual contracts COVID-19, we must determine several factors regarding this particular case. First, we decide the length of the infection, or the number of days until the individual will recover (or pass away if the infection is deemed "fatal.") To do so, we choose a random value in the 7-10-day range as governed by the INFECTION_LENGTH variable. Next, we determine whether this individual is an asymptomatic carrier, the odds of which are based on either the ODDS_ASYMPTOMATIC_TEACH or ODDS_ASYMPTOMATIC_STUD, depending on whether the individual is a student or teacher. If the individual is not an asymptomatic carrier, we must determine the length of the incubation period, or the number of days until the individual becomes symptomatic. Lastly, we must assign the severity of the illness based on probabilities related to the individual's age; we reference the relevant SEVERITY_WEIGHTS to do so.

Once this default model was created, we constructed our three specific scenarios to be simulated. Our first scenario is referred to as "No Precautions," in which we aimed to simulate the risk of implementing no changes to school procedure and proceeding as if COVID-19 was of no concern. To do so, we copied the default model and implemented two major additions: a daily lunch period and a periodic school-wide assembly. Everyone was divided into one of three lunch periods, which operated identically to the classroom in terms of exposures. However, the risk of each exposure was lessened by 90% to account for the differences in the classroom and lunchroom environments. Lunchrooms contain far more students than individual classrooms, which means there are more opportunities for exposure overall. However, lunchrooms are much larger than classrooms and involve far fewer instances of "close contact," which would predicate simulating an exposure. Lunch periods are also much shorter than class periods, meaning there are far fewer instances of "close contact" during the allotted time. Exposure odds were also lessened by 90% during school-wide assemblies for similar reasons; shorter periods of exposure, larger rooms, and more individuals, meaning lower odds of "close contact" between a specific individual. School assemblies, however, were held three times throughout the semester - one a third of the way, one halfway, and one two-thirds of the way through the semester.

Our second scenario is referred to as "Minor Precautions," and implements two major changes from the default model. The first is the implementation of social distancing in the classroom, which reduces the spread of COVID-19 by approximately 60%. (Kissler et al., 2020) The second was the implementation of testing upon a confirmed case of COVID-19. When a student or teacher in the Minor Precautions model becomes symptomatic and is removed from the classroom, all other individuals in that classroom are tested, and any that test positive are removed from school until recovered. Note that if an individual is an asymptomatic carrier, they will never

become a confirmed COVID-19 positive case in this simulation, and thus will never trigger a round of testing.

Our third scenario is referred to as "Moderate Precautions," and is an extension of the previous Minor Precautions scenario. In this model, we implement both social distancing and the use of surgical masks, which is reported to reduce the spread of COVID-19 by approximately 60% as well. (He, X., 2013) On top of this, we implement similar testing procedures as in the Minor Precautions model; anytime a COVID-19 case is confirmed in a given school, that school launches a series of tests. However, in the Moderate Precautions model, we test not just a particular classroom but the entire school; any COVID-19 positive individual is removed from the school until recovered.

Data Analysis

Once these three scenarios were built, we ran the simulation of each scenario 20 times over 126 days, the approximate number of days in the Fall 2019-2020 semester of Spartanburg County elementary schools. Note that this figure includes weekends - in our model, individuals are still exposed to external sources of infection on weekends but are not exposed to other students or teachers.

As expected, we saw substantially more cases arise in simulations of the No Precautions scenario than either the Mild Precautions or the Moderate Precautions scenarios. As we see in Figure 5.1, a median of 858 more cases of COVID-19 were generated in the No Precautions scenario as opposed to Mild Precautions; the margin between Mild Precautions and Moderate Precautions was much smaller at approximately 170.

Scenario	total	median	max	min	stdev
Minor Precautions	7406	384.0	413	195	46
Moderate Precautions	4385	218.5	272	147	29
No Precautions	24643	1242.0	1630	1028	138

Figure 5.1

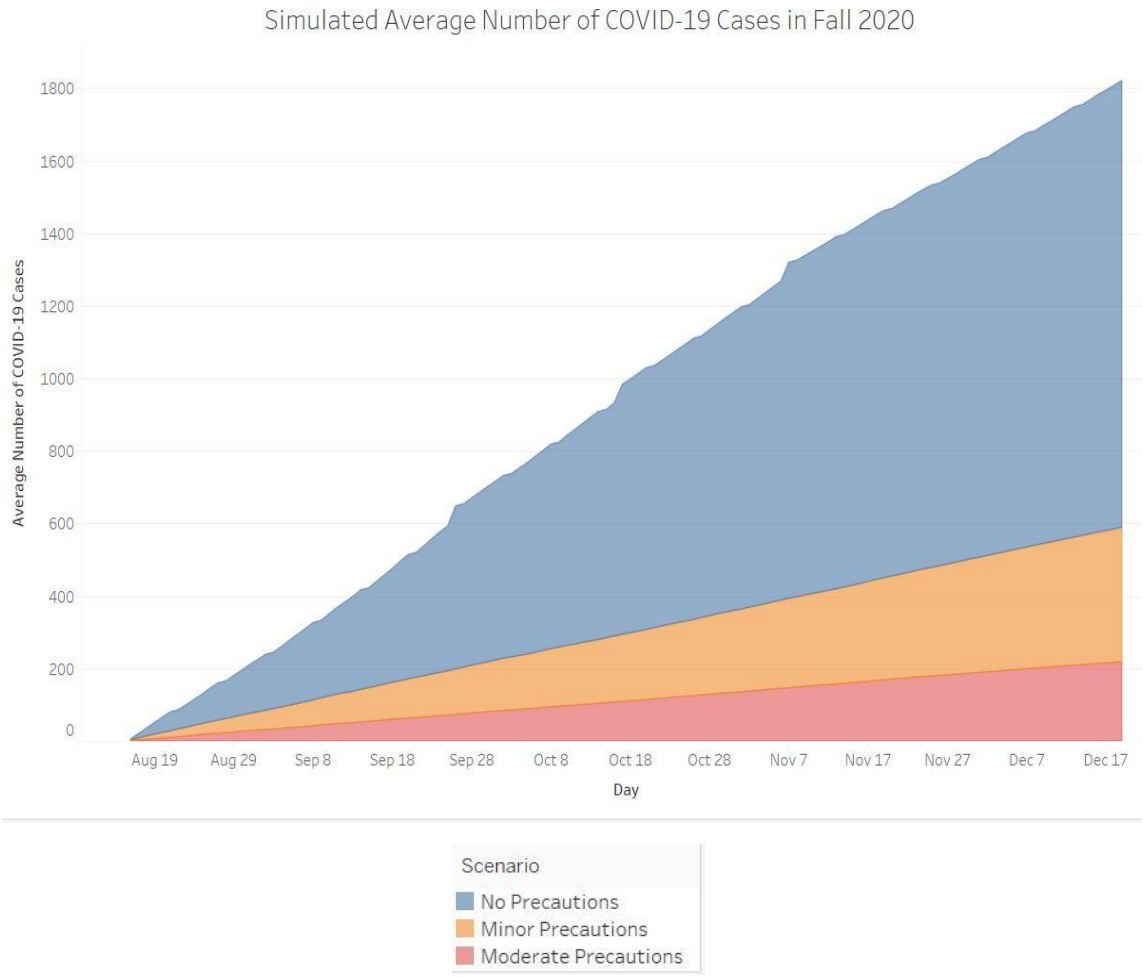

Figure 5.2

Across all scenarios, 19% of COVID-19 cases were Primary cases, while 81% were Secondary cases. In our No Precautions scenario, however, only 9.3% of cases were Primary, while 90.7% were Secondary cases generated in the school scope. For context, 69.4% of cases in the Minor Precautions scenario were Secondary cases, while only 45.9% of cases in Moderate

Precautions were Secondary – over half of the cases of COVID-19 in this scenario were generated outside of the scope of our school. Figure 5.3 breaks down the specific summary statistics regarding Primary versus Secondary cases in each of the three scenarios.

Scenario	Infection_Type	total	median	max	min	stdev
Minor Precautions	Primary	2266	111.0	132	101	9
Minor Precautions	Secondary	5140	273.0	299	93	44
Moderate Precautions	Primary	2371	114.0	156	104	14
Moderate Precautions	Secondary	2014	105.5	128	39	21
No Precautions	Primary	2293	113.5	137	102	10
No Precautions	Secondary	22350	1130.0	1493	897	136

Figure 5.3

As seen in Figure 5.4, the majority of COVID-19 cases in this simulation were in students, which is unsurprising given our population had 6x more students than teachers. It is worth noting this ratio varies significantly between scenarios, with 5x more students contracting COVID-19 in the No Precautions scenario as opposed to 12x more students in the Minor Precautions scenario and 8x more students in the Moderate Precautions scenario; overall this is likely due to variance.

Scenario	Person_Type	total	median	max	min	stdev
Minor Precautions	Student	6840	352.0	385	159	50
Minor Precautions	Teacher	566	27.0	51	10	10
Moderate Precautions	Student	3875	189.5	240	117	30
Moderate Precautions	Teacher	510	23.5	41	17	6
No Precautions	Student	20523	1028.5	1362	858	118
No Precautions	Teacher	4120	204.5	268	161	25

Figure 5.4

Lastly, we break down output data by case severity scenario by scenario, beginning with No Precautions. As expected, the vast majority of students were asymptomatic or suffered mild

cases of COVID-19; out of 9,408 students per simulation, we saw a median value of 17 reach a point where hospitalization due to COVID-19 symptoms was required. Our teacher population also saw a definitive majority of cases result in asymptomatic or mild illness; 79% of COVID-19 positive teachers fell into this category. What we saw, however, were several cases of COVID-19 each simulation that required ICU admission, and approximately one fatality per simulation due to COVID-19.

Scenario	Person_Type	Severity	total	median	max	min	stdev
No Precautions	Student	asymptomatic	5728	276.5	399	241	37
No Precautions	Student	hospitalized	327	17.0	24	6	5
No Precautions	Student	mild	14468	717.5	942	604	80
No Precautions	Teacher	asymptomatic	767	38.0	52	28	7
No Precautions	Teacher	fatal	19	1.0	3	1	1
No Precautions	Teacher	hospitalized	667	32.0	49	24	7
No Precautions	Teacher	ICU	163	8.0	14	3	3
No Precautions	Teacher	mild	2504	128.0	165	88	19

Figure 5.5

Next are the results of the Minor Precautions scenario. These results generally mirror those of the No Precautions scenario at a smaller proportion, outside of some level of random variance. This follows logically, given that the measures put in place were to prevent the spread of COVID-19, but did not have any effect on the severity of those cases when they did arise. One important note to make is that only five fatalities occurred in this scenario; in three-fourths of our simulations, no fatalities occurred, as opposed to No Precautions, where virtually every simulation resulted in a fatality.

Scenario	Person_Type	Severity	total	median	max	min	stdev
Minor Precautions	Student	asymptomatic	1927	99.5	112	43	15
Minor Precautions	Student	hospitalized	97	4.5	8	2	2
Minor Precautions	Student	mild	4816	251.0	282	113	37
Minor Precautions	Teacher	asymptomatic	82	4.0	8	1	2
Minor Precautions	Teacher	fatal	5	1.0	1	1	0
Minor Precautions	Teacher	hospitalized	119	5.0	13	1	3
Minor Precautions	Teacher	ICU	24	1.5	5	1	1
Minor Precautions	Teacher	mild	336	14.5	35	5	7

Figure 5.6

Finally, the results of our Moderate Precautions scenario. Again, these results are proportionally similar given all scenarios were based off of identical severity statistics. Note that two fatalities occur in our 20 simulations, or one in every ten. It is also worth noting, however, that we see 25 cases requiring ICU admission, as opposed to the 24 in Minor Precautions; this can be chalked up to statistical variance, as again identical severity statistics were used. In a similar vein, note that 21.1% of cases in the Moderate Precautions scenario were asymptomatic, while only 14.5% of cases in the Mild Precautions scenario were asymptomatic. There is no explanation for such a difference outside of statistical variance, though the difference seems quite drastic at face value.

Scenario	Person_Type	Severity	total	median	max	min	stdev
Moderate Precautions	Student	asymptomatic	1086	56.0	71	35	10
Moderate Precautions	Student	hospitalized	55	3.0	6	1	2
Moderate Precautions	Student	mild	2734	135.5	169	81	21
Moderate Precautions	Teacher	asymptomatic	108	5.0	10	3	2
Moderate Precautions	Teacher	fatal	2	1.0	1	1	0
Moderate Precautions	Teacher	hospitalized	82	4.0	6	1	2
Moderate Precautions	Teacher	ICU	25	1.0	3	1	1
Moderate Precautions	Teacher	mild	293	14.5	26	8	4

Figure 5.7

Discussion

It is quite clear that resuming elementary school activity with no precautions in place would be highly irresponsible and result in a substantial increase in the rate of COVID-19 transmission. While it is true that school-aged children are significantly less susceptible to more severe cases of COVID-19, (per CDC, 2020) there is uncertainty regarding the long-term ramifications of battling the virus; researchers have noted evidence that COVID-19 may cause long-term damage to the cardiovascular system, the neurological system, the kidneys, and the lungs. (Venicia-Suarez, A., 2020) Beyond this, we must consider that when a student tests positive for COVID-19, they must be removed from the school environment until there is confidence that the individual is no longer capable of transmitting the virus. This interruption is likely a matter of weeks, which will undoubtedly harm the learning experience of the student, who is now behind the learning curve. We must also consider the risk of students transmitting the virus to family members. Alexander Otto cites the spread of COVID-19 within family units as "the driver of the infection in China," with initial rates as high as 10% before awareness and precautions dropped the rate to 3%. (Alexander Otto, 2020) While elementary-aged children face little risk of severe or fatal outcomes from COVID-19 infection, they may spread the virus to more vulnerable members of our society, such as parents or grandparents who have no choice but to care for the child regardless of risk.

One consideration as to the efficacy of our proposed scenarios is the financial cost. Instituting social distancing in schools should come at little to no monetary cost, although if school buses are at half capacity that would add high cost to the equation. We would also have to figure in the cost of single-use surgical masks if the school district did not mandate that each individual

bring his or her own mask to school. Another option is providing individuals with washable masks that could be reused. However, the most significant financial burden proposed in our Minor and Moderate Precautions scenarios would be the COVID-19 PCR tests. A recent New York Times article noted that health care providers generally charge between $50-$200 per PCR test, noting that "LabCorp, one of the country's largest diagnostic testing firms, bills insurers $100 for its tests." (15)

Across our twenty simulations, a median of 281 individuals became symptomatic at some point during the fall semester in the Mild Precautions scenario. In our simulation, some of these individuals would likely have been caught during testing and would not have triggered another round of testing; however, for the sake of discussion, we will assume all of these cases required a new round of testing. In our Minor Precautions scenario, when an individual began showing symptoms of COVID-19, we tested all students and teachers in the particular classroom that individual was in. We estimated that an average classroom in Spartanburg County has nine students and 1.5 teachers (half of the classrooms were assumed to have teaching assistants as well as primary teachers.) 281 rounds of testing on an average of 10.5 individuals is approximately 2951 PCR tests; at an estimated cost of $100, this would cost the seven Spartanburg County school districts a total of $295,100 across the fall semester, with an average of $7,567 per school.

Far more costly is our Moderate Precaution scenario, in which we test every individual in the school upon confirmation of a positive COVID-19 case. Across our twenty simulations, a median of 159 individuals became symptomatic at some point during the fall semester in this scenario. For the sake of discussion, let us assume that 10% of the median 159 individuals that became symptomatic were identified as COVID-19 positive during testing, given the breadth of testing in this scenario. We estimate that an average school in Spartanburg County has a combined

280 students and teachers. After eliminating 10% of the 159 symptomatic individuals, we are left with 143 rounds of testing across all schools. 280 * 143 = 40,400 PCR tests throughout the Fall semester. At $100 per test, we estimate a total cost of $4,040,000 across all schools throughout the Fall semester, with an average of $103,590 per school. While it is true that this additional testing would lead to more thorough identification of COVID-19 cases and fewer cases overall, it is difficult to argue that the marginal benefit is worth an additional $96,023 per school.

Given the consideration of financial cost, it seems that the ideal approach for most school districts would be to implement a blend of precautions used in the Minor and Moderate Precautions scenarios. Implementing social distancing measures as well as the use of surgical masks reduces the risk of COVID-19 transmission dramatically and implementing a testing procedure akin to the one simulated in the Minor Precautions scenario will limit the spread of cases that do arise. Other precautions and procedures not simulated are also recommended; throughout cleaning of surfaces including (but not limited to) desks, door handles, and school buses on weekends and after a confirmed case of COVID-19 at a school will also reduce the spread of the virus via surface transmission; while fomite transmission is not the main driver of spread, a New York Times suggests that the virus can live on surfaces such as plastic or steel up to three days. (Mandavilli, A., 2020)

Proposed Solutions

Based on the South Carolina Department of Education, different models are being considered to honor the Governor's requests. This includes traditional, hybrid, virtual learning, and online academy. These models are designed to place the health and well-being of the students as a top priority. These also allow flexibility to easily adjust depending on the rise and

fall of cases in the area. A hybrid model will be introduced but the choice remains to the parents on whether to enroll the students in a fully online academy.

A traditional model is focused on face to face instructions with precautions incorporated into the school day. The curriculum will be provided within software already known to the students. According to SDEHC, the precautions include:

- Hand sanitizer provided all around the school
- Cleaning and sanitation of 'high touch surfaces'
- Limited physical interaction
- Capacity regulations throughout the school.

A hybrid school model is focused on dividing two groups and these two groups will receive an alternative schedule. According to SDEHC, these two groupings include:

- Group A will have face-to-face instructions two days of the week and works remotely for the remainder. Wednesday will be all remote learning in order to sanitize the building.
- Group B will have face-to-face instructions two different days of the week from group A and work remotely for the remainder. Wednesday will be all remote in order to sanitize the building.
- Teachers will use Wednesdays as planning days.

As mentioned in the SDEHC lesson plans, the precautions include:

- Maximize social distancing within the classroom
- Limit physical interactions among the students and teachers
- Establish social distancing measures between the teacher's desk and front board

- Utilize the largest spaces in the school to promote social distancing.

A virtual learning model is promoted for high-risk areas and are designed to keep both students and teachers in mind. In this model, students will not be returning to school and be attending online instruction. Students will still need to meet the expectation of attending school.

As mentioned in the SDEHC lesson plans, the precautions include:

- All students would receive a new Chromebook device to accommodate the online schedule.
- Printed instructional manuals will be provided if necessary
- Detailed communication to clearly define expectations
- An assigned technology support area for any technical difficulties

A family classroom model is promoted based on lower-risk areas. In this model, elementary students and staff allow for them to return but with specific restrictions.

As mentioned in the SDEHC lesson plans, the precautions include:

- Remain in one classroom throughout the duration of the school day
- Breakfast and lunches will not be served in the cafeteria but instead in the classroom
- Clean and heavy sanitation measures will be promoted
- Identify traffic and flow issues throughout the schools
- No large assemblies
- Face masks only in large group gatherings

Lastly, the SDEHC has introduced the Spartanburg Online Academy to accommodate students that are not comfortable with leaving the comfort of their own homes.

Limitations & Future Research

In order to ensure we constructed a model that was both logically sound and fully backed by publicly available data, several features in our initial theoretical model were discarded. Potentially the most critical is the concept of herd immunity or the idea that the spread of COVID-19 or any virus can be slowed and eventually ended when a large enough proportion of the population is immune to the virus. Early on, there was much debate over whether an individual who was once COVID-19 positive and then tested COVID-19 negative could once again test COVID-19 positive. Theoretically, this is a potential possibility due to the existence of false-negative tests, or a COVID-19 test that returns a negative result when the patient is indeed still positive. (Xiao, A. et al., 2020) This could also occur in a patient who is able to reduce the viral load in his or her system to a point it is undetectable by a nasal swab test, but is not able to totally eliminate the virus, leading to a period of remission where the patient is recovered, and any COVID-19 test returns negative, but there is still a possibility of the virus repopulating to the degree that the patient is once again considered COVID-19 positive. (Cha, A., Johnson, C., 2020). A prime example of this is HIV infection, which can be controlled by anti-retroviral (ART) therapy, but most be continued indefinitely to avoid relapse, as "interruption of ART leads to rapid recrudescence of infection from long-lived latently infected cells." (Pinkevych M., et al., 2016) Lastly, a potential concern is that even if the presence of COVID-19 antibodies meant that a recurring infection was impossible, it is feasible that a COVID-19 positive individual could transmit the virus to the individual, who then could transmit the virus others before his or her immune system was able to destroy the virus. Even though the carrier was never sick, the carrier may indirectly infect other individuals with whom the carrier came into close contact with.

Another key factor in the refinement of this statistical model is the availability of larger sets of data regarding proportions of COVID-19 patients who are asymptomatic, namely in children. The study referenced in this model conducted by Qui and others had a sample of only 36 children, far too small a sample to be satisfactory – though this is no fault of the authors, who were studying the epidemiological features of the disease. (Qui, H., et al., 2020) Early studies do not have the luxury of focusing on asymptomatic carriers, as the vast majority of research was dedicated to symptomatic patients, and rightfully so – we needed to focus on comprehending the virus and treating those who fell ill before attempting to prevent its spread. However, now that we are four months into the United States COVID-19 outbreak, it is imperative that we dedicate more research towards studying asymptomatic carriers.

Other factors were excluded from the model due to complexity or simple time constraints rather than a dearth of data. The inclusion of false-positive and negative tests would be the simplest to integrate, though this serves only to add more variance to the model and its results. No consideration was given to whether COVID-19 cases that resulted in hospitalization or beyond would result in lengthier periods of infection, and thus longer absences from school. Another future consideration is the incubation period – in this model, individuals were considered to be COVID-19 positive the instant they were exposed to the virus in a manner that would eventually lead to infection; in reality, there is some period of time after exposure where the individual would not test positive for COVID-19, despite some trace of the virus being in their system.

Some of these factors were related to the modeling of the school rather than the COVID-19 virus. The use of school buses is likely unavoidable in any scenario where students return to in-person classrooms; similarly, further research on the spread of COVID-19 in lunchrooms, assemblies, hallways, and any other area outside of the classroom is essential. For that matter,

further research on transmission within the classroom would be valuable; our data was based on individuals who had "close contact" with COVID-19 positive patients but was not measured in a classroom setting. (Alexander Otto, M., 2020) Lastly, the incorporation of other faculty and staff at the school, as well as the families of students and teachers alike, would give a more robust picture of the scope of secondary infections that result from in-person elementary schools.

References

1. Johns Hopkins Medicine. (2020). *What you Need to Know from Johns Hopkins Medicine.* Retrieved from https://www.hopkinsmedicine.org/coronavirus
2. CDC. (2020). *Symptoms of Coronavirus.* Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html
3. South Carolina Department of Education. (2020). *School District Reopening Plans.* Retrieved from https://ed.sc.gov/newsroom/covid-19-coronavirus-and-south-carolina-schools/school-district-reopening-plans/
4. Soland, J., Kuhfeld, M., Tarasawa, B., Johnson, A., Ruzek, E., & Liu, J. (2020). *The impact of COVID-19 on student achievement and what it may mean for educators*. Retrieved from https://www.brookings.edu/blog/brown-center-chalkboard/2020/05/27/the-impact-of-covid-19-on-student-achievement-and-what-it-may-mean-for-educators/
5. Fleming, Nora. (2020). *Why Are Some Kids Thriving During Remote Learning?* Edutopia, George Lucas Educational Foundation, Retrieved from www.edutopia.org/article/why-are-some-kids-thriving-during-remote-learning.
6. Medlineplus. (n.d.). *School-Age Children Development: MedlinePlus Medical Encyclopedia.* U.S. National Library of Medicine. Retrieved from medlineplus.gov/ency/article/002017.htm.
7. SCDHEC. (2020). *COVID-19 Cases in SC.* [Data Visualization]. Retrieved from https://www.scdhec.gov/infectious-diseases/viruses/coronavirus-disease-2019-covid-19/sc-testing-data-projections-covid-19.
8. Census Reporter. (2019). *Spartanburg County, SC.* [Data Set]. Retrieved from https://censusreporter.org/profiles/05000US45083-spartanburg-county-sc/.
9. California Department of Public Health. (2020). *Cases and Deaths Associated with COVID-19 by Age Group in California*. [Data set]. Retrieved from https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/COVID-19-Cases-by-Age-Group.aspx
10. *Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020.* MMWR Morb Mortal Wkly Rep 2020; 69:343-346.
11. Qiu, H., Wu, J., Hong, L., Luo, Y., Song, Q., & Chen, D. (2020). *Clinical and epidemiological features of 36 children with coronavirus disease 2019 (COVID-19) in Zhejiang, China: An observational cohort study.* The Lancet Infectious Diseases, 20(6), 689-696.
12. U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), *"Public School Teacher, BIE School Teacher, and Private School Teacher Data Files,"* 2007–08. Retrieved from https://nces.ed.gov/pubs2009/2009324/tables/sass0708_2009324_t12n_03.asp.
13. He, X., Reponen, T., Mckay, R. T., & Grinshpun, S. A. (2013). Effect of Particle Size on the Performance of an N95 Filtering Facepiece Respirator and a Surgical Mask at Various Breathing Conditions. *Aerosol Science and Technology*, *47*(11), 1180-1187.
14. Kissler, S. M., Tedijanto, C., Lipsitch, M., & Grad, Y. (2020). *Social distancing strategies for curbing the COVID-19 epidemic.*

15. Alexander Otto, M. (2020). *COVID-19 update: Transmission 5% or less among close contacts.*
16. Mizumoto, K., Katusishi, K., Zarebski., Chowell, G. (2020). *Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020.*
17. Beeching, N., Fletcher, T., Beadsworth, M. (2020). *Covid-19: testing times.* BMJ 2020;369:m1403.
18. Pinkevych M, Cromer D, Tolstrup M, Grimm AJ, Cooper DA, et al. (2016). *HIV Reactivation from Latency after Treatment Interruption Occurs on Average Every 5-8 Days—Implications for HIV Remission.*
19. Xiao, A., Tong, Y., Zhang, S. (2020). *False negative of RT-PCR and prolonged nucleic acid conversion in COVID-19: Rather than recurrence.*
20. Cha, A., Johnson, C. (2020). *Can you get coronavirus twice? Doctors are unsure, even as* anecdotal reports mount.
21. Veciana-Suarez, A. (2020). *What are the Long-Term Effects of COVID-19?*
22. Kliff, S. (2020). *Most Coronavirus Tests Cost About $100. Why Did One Cost $2,315?*
23. Mandavilli, A. (2020). *How Long Will Coronavirus Live on Surfaces or in the Air Around You?*
24. CDC. (2020). *Duration of Isolation & Precautions for Adults.*
25. Hersh, E. (2020). *How Long Is the Incubation Period for the Coronavirus?*