Journal of Research High School

Volume 2021 (2) 14 - 36
ISSN 2688-3651 [online]

Projected Impact of COVID-19 on the Reopening of Universities in Fall 2020

Abigail Mulry[1,3*], Aditya Pillutla[2,3], Caleb Marsh[3], Stephanie Thomas[3], Melanie Prater[3], Lori Tyler[3], Kelsey Thomas[3]

[1]Northern Guilford High School, NC, USA, [2]Enloe High School, NC, USA, [3]Appalachian State University, NC, USA

Received October 4, 2020; Revised June 26, 2021; Accepted, July 1, 2021

Abstract

In the summer of 2020, the United States faces a situation in which schools are forced to weigh the costs and benefits of reopening in fall 2020 while confronted with the COVID-19 pandemic, and to what extent they should do so. We chose to evaluate the risks of reopening by utilizing a simulation to model the effects of introducing one student infected with SARS-CoV-2 (COVID-19) to ten different university campuses in order to predict how the virus would spread amongst the student populations at each one. By developing case studies for each university, we were able to simulate the impacts COVID-19 could have at several different percentages of overall attendance. This representative modeling system helped us better judge the number of students that should be allowed on campus at different sizes of universities. Through our study, we determined that for US schools to proceed with in-class instruction, many safety measures, inspired by those successfully taken by other countries, will need to be put in place and enforced strictly. Our modeling demonstrated that larger universities should limit the number of students they allow back on campus, preferably to under 25% of regular attendance to reduce infections and deaths, and all but the smallest schools should not consider bringing more than half of their enrolled students back to campus in the fall. Through our research we were able to predict outcomes of 40 different potential upcoming situations and develop a rough guideline for universities to refer to.

Keywords: COVID-19, SARS-CoV-2, novel coronavirus, coronavirus, university reopening fall 2020, college reopening, epidemiological modeling

1. Introduction

In the midst of the COVID-19 pandemic, universities throughout the United States of America were facing a dilemma of whether to reopen their campuses and pose a health risk to their students and faculty, or to go fully online and lose as much as half of their revenue and lower the quality of their students' education (Wood 2020). Despite attempts to contain the virus, COVID-19 spread throughout the US in massive waves, with greater than 4.3 million diagnosed cases across the country and resulting in almost 150,000 deaths as of July 27, 2020 ("United States," 2020). This led to the widespread closing of schools and universities in March 2020 with most students being sent off-campus to complete the current term. Yet 5 months later, experts were still unsure of whether it was safe to return to school. Contrarily, in many other countries such as Denmark and Singapore, students returned to school and

* Corresponding Author
amulry6917@gmail.com

Advisor: Dr. Caleb March
ccmarsh300@gmail.com

followed strict safety guidelines enforced by the government in order to stay healthy and limit the spread of the SARS-CoV-2 virus (henceforth referred to as COVID-19) (Melnick & Darling-Hammond, 2020). In France, primary schools reopened as early as May 11 with mild success. This reopening ultimately led to some social divide between the upper class that decided to return to school and the lower class that largely stayed at home for various reasons (Williamson, 2020). In Taiwan, universities never fully closed, but thorough guidelines to contain the virus were strictly enforced by various task force teams at universities, and with much success, resulting in only 7 confirmed cases in 6 Taiwanese universities as of June 18, 2020 (Cheng et al., 2020). However, these countries' successes in reopening schools and universities largely had to do with their containment of the virus early on in the year (Cheng et al., 2020; Domenico et al., 2020). The same policies would not be as effective in the US, where there were more than 4.3 million COVID-19 cases as of July 27, 2020, with more than 60,000 new cases per day as of July 29, 2020 ("United States," 2020). Therefore, it was important to examine the potential spreading scenarios if universities were to allow students to return to campus, in order to weigh the risks and benefits of reopening schools and universities in-person during the fall term. Looking at the methods other countries have used to contain COVID-19, and by analyzing data published by colleges, the purpose of our research was to simulate and model the behavior of COVID-19, if universities were to reopen at full, 75%, 50% or 25% capacity. Therefore, we put forth the question "by using data released by organizations and universities about COVID-19 cases and student population numbers through July 21, 2020, how was COVID-19 expected to impact American schools' reopening in Fall 2020?"

In order to learn as much as possible about the effects of COVID-19 and reopening, we first had to do background research on the virus, and then look to studies performed in other countries in order to determine how reopening could look in the US. To find the relevant literature available, we searched Google Scholar and other scholarly search tools using keywords such as "COVID-19", "school reopening", "university plans", "Fall 2020", etc. We were able to come across valuable information that helped us understand better the impacts of COVID-19 on the public health of society as a whole, and learn more about the disease, how it spread, etc.

COVID-19 (coronavirus disease 2019) is a vascular illness caused by SARS-CoV-2 that most commonly affects the respiratory system of the body. It is spread through respiratory droplets, close person-to-person contact, and infected surfaces. Worldwide, there were over 15 million cases, with more than 600,000 deaths and more than 100,000 new cases per day as of July 24, 2020 (Centers for Disease Control and Prevention [CDC], 2020). According to the CDC (2020),

> The coronavirus disease 2019 (COVID-19) pandemic may be stressful for people. Fear and anxiety about a new disease and what could happen can be overwhelming and cause strong emotions in adults and children. Public health actions, such as social distancing, can make people feel isolated and lonely and can increase stress and anxiety.

It is clear that COVID-19 has taken a toll on the mental health of Americans in addition to the adverse economic and physiological effects, and this may be part of the reason why many universities are pushing to reopen in fall 2020.

1.1 Education

Based on a review of the literature available at the time and based on other countries that have reopened schools, it seems clear that if universities are to be opened, strict safety guidelines need to be followed so as to spread COVID-19 as little as possible (Wood, 2020; Sheikh et al., 2020; Cheng et al., 2020). However, other countries have all handled the COVID-19 pandemic differently than the United States has, and this has led to differences in the way schools have been and should be reopened in each country.

France

A study performed in the area of Île-de-France looked at the different scenarios in which schools would reopen in the region, and performed statistical tests to determine when and which methods should be used in the reopening of preschools to K-12 schools (Domenico et al., 2020). The researchers found that,

> Reopening schools after lifting lockdown will likely lead to an increase in the number of COVID-19 cases in the following 2 months, even with lower transmissibility of children, yet protocols exist that would allow maintaining the epidemic under control without saturating the healthcare system (Dominica et al., 2020).

They also found that reopening preschools and primary schools alone would not overwhelm the healthcare system if opened on May 11. However, even with all necessary safety protocols, reopening middle and high schools would overload the healthcare system and rapidly increase the spread of COVID-19. The authors recommend against reopening middle and high schools at full capacity (Domenico et al., 2020). Many colleges in the US, with young adult/adolescent age students, were planning on reopening at full capacity, which is exactly what the study recommends against, even though it was written at a time when there were only about 56,000 active cases in all of France (around 139,000 total cases), specifically when the country was in lockdown and shortly after researchers had thought new cases had "peaked". In addition, the US is a larger area with a larger population with many more cases of COVID-19 than Île-de-France, with comparatively less people inclined to wear masks and social distance. COVID-19 is spreading quicker than ever in the US currently, and the advice intended for a smaller region with a smaller population would not be fully applicable to the US; reopening colleges at full capacity would most likely have a larger impact on the spread of COVID-19 in the US than in France. However, healthcare systems and schools are both structured differently in the US than in France, so this also could have an impact on the spread of COVID-19.

<u>*Taiwan*</u>

Another study examined how Taiwan, an island nation southeast of China that currently has fewer than 15 COVID-19 cases, handled the virus in the university setting (Cheng et al., 2020). Taiwan maintained strict safety regulations from the very beginning of the epidemic, and universities never fully closed or went into lockdown, as they did in the US;

> The guidelines delineated creation of a task force at each university; school-based risk screening based on travel history, occupation, contacts, and clusters; measures on self-management of health and quarantine; general hygiene measures (including wearing masks indoors); principles on ventilation and sanitization; regulations on school assemblies; a process for reporting suspected cases; and policies on school closing and make-up classes (Cheng et al., 2020).

In addition, if even one student on campus tested positive for COVID-19, class would be suspended, and if two or more students/faculty tested positive, the university would be closed for 14 days. These stringent safety guidelines are what kept the number of COVID-19 cases in Taiwan low, and helped the country make a quick economic recovery. However, the same advice on reopening universities could have different effects if implemented in the US, as cases in the country have been rising at a rate greater than ever before, greater than Taiwan had ever experienced. Nonetheless, it's important to closely examine what Taiwan has done to keep the country safe.

1.2 Distance Learning

A literature review on reopening schools after the COVID-19 lockdown examined the different methods that various countries have employed. Sheikh and his colleagues (2020) found that one of the best methods is one that has recently been used by Denmark- outdoor classrooms in which students wear masks and stay at least a 2 meters radius away from their peers. This method requires a lot of quiet outdoor space with minimal distractions and air pollution, which some schools may not have available to them in the US (especially in dense urban areas). Online learning was another one of the methods that was found to have worked the best (Sheikh et al., 2020). However, if universities in the US went all online, universities would lose a lot of money that's crucial to paying their faculty/staff, maintaining the campus, funding research and scholarships, etc. In addition, many students may prefer in-person classes to online classes for various reasons including peer motivation and escape from home environments that may be abusive or unsafe. Online classes are less effective at educating than in person classes have shown to be, and would likely result in a decrease in both overall learning and academic integrity (Protopsaltis & Baum, p. 1-3, 2019). On the other hand, if universities used Denmark's strategy, they would need more space to do so, and both the universities in urban centers with limited land space and large universities with many students would find this a challenge.

Wood (2020) stated that going fully online for fall semester means universities would lose half their revenue, meaning they're likely to go bankrupt. Most schools are employing safety policies similar to Taiwan and South Korea on their campuses, but students are unlikely to strictly adhere to rules, meaning that universities could result in COVID-19 spreading at rates even faster than ever before.

1.3 Reopening in the US

Another author compiles the reopening plans of more than 1000 US universities and finds that about half of the universities are planning return to campus in the fall fully in-person, 35% are planning to use a hybrid model that combines virtual and in-person classes, 12% are planning for online, and 3.5% have not yet chosen a confirmed method of reopening (Figure 1). With half of universities inviting all students back to campus and with all in-person classes, they pose a major health concern to their students (Chronicle Staff, 2020). It is critical that the safety of the students is prioritized in all cases, and the universities must not only implement maximum safety and cleanliness requirements, but also understand the risks of following through with such plans.

England

A third analysis of the COVID-19 school reopening crisis analyzes various teachers' responses to a survey on England's school reopening strategy (See et al., 2020). See and colleagues found that the majority of teachers in England had a high distrust of the government when it came to delegating the safety of returning to school. They had particularly negative responses in regards to their sense of safety upon a potential return to school June 1st, with most considering the situation to be much too dangerous. Most teachers felt unsafe and that the policies individual schools would put into place would not be nearly enough to create a safe environment for both students and teachers (See et al., 2020).

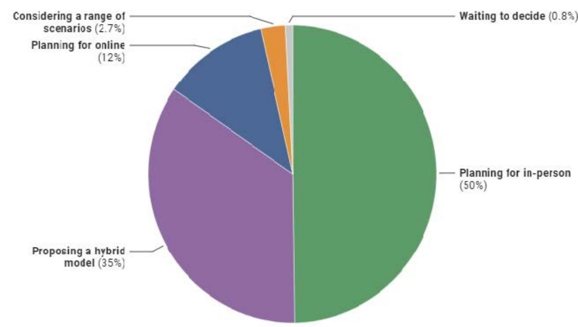

Figure 1. US University reopening plans ("The coronavirus", 2020). Pie chart describing the range of universities planning to open "in-person", "hybrid" (some in-person classes, some online classes), completely "online", and those "waiting to decide", or "in consideration"

2. Methods

As it became clear that guidelines needed to be established for universities to consider how they should reopen in the fall, we realized it was necessary for us to fill the void in research by answering the question of "by using data released by organizations and universities about COVID-19 cases and student population numbers, respectively, through July 21, 2020, along with data from other countries who have returned to school, how was the coronavirus expected to impact American schools' reopening in fall 2020?" To do this, we gathered information from various sources which considered how other countries had managed a safe return to in-person educational practices. We understood that in order to make any predictions or to give universities valid claims to analyze and guide them, we would need to use a modeling system, where variables for each university were calculated and set in order to give a realistic depiction of several case scenarios of what could happen in the fall. Given that the United States is much larger and suffered a much greater spread of COVID-19 than many countries who had returned to school thus far, it was widely understood that exactly the same practices would not be enough to contain the spread of the virus in universities. In order to test if this was true, and to show to what extent of danger universities faced, we chose to use a graphing simulator that would illustrate how many cases, deaths, and immunities would result from 40 different situations among 10 different sized universities. We hypothesized that as the number of students colleges allow on campus increases, the number of semester COVID-19 cases would increase exponentially.

In performing this study, we collected data from ten colleges across the United States (Harvard University, University of Southern California,Texas A&M University, University of Central Florida, Carnegie Mellon University, Brigham Young University, Johns Hopkins University, Tulane University, University of Alaska Southeast, and Purdue University) to perform an individual case study of each school. In making our model, we made sure to include an assortment of school sizes and locations so as to accurately represent universities in different settings. The entire student population of each school was calculated using current university data posted on their respective websites (as of July 21, 2020), other than Carnegie Mellon, who has not released current enrollment, hence we used 2019 enrollment numbers, and Purdue University, who has only released 2018 enrollment numbers. The number of students that would be permitted on campus at 25, 50, and 75 percent capacities were modeled using the original documented total population of students on campus (undergraduate and graduate), multiplied by the designated factor, and rounded down to the nearest person. Some of the data published on the websites of each college may not have been updated as of July 21, 2020, and the numbers we utilized in our modeling and analysis may have been enrollment records from 2019 or previous years if not noted online that they were current numbers. In addition, the use of modeling with both undergraduate students and graduate students harbors some error due to the unlikelihood of graduate students spending similar amounts of time on college campuses as undergraduate students would.

The first variable that the simulator we used made use of was an initial population. We modeled situations in which 100%, 75%, 50%, or 25% of the enrolled undergraduate and graduate students were to be on campus with all classes being in-person in the fall (Table 1). We understand that many of these campuses, such as Harvard University, University of Southern California, and Texas A&M University to name a few, are offering all classes in an entirely online curriculum for students who wish not to risk exposure while taking classes on campus and classrooms. Six out of the ten universities we studied are adopting a hybrid model that combines online learning with in-person classes for fall 2020 as of July 28, 2020. Most universities have all virtual learning as an option for students that do not want to go on campus. The simulation we performed is solely based on specific set variables and is only modeling hypothetical situations that may occur at different schools if very specific guidelines are met. Despite this, through our study we would be able to produce viable estimates of how the disease could spread among different sizes of populations in an enclosed space with only one patient zero in each case. Using this, universities could begin to understand the effects of introducing not just one, but possibly more students back on campus who were infected with the novel coronavirus, and evaluate to what extent the risk is worthwhile.

3. *Instrumentation and Data Analysis*

In order to model our hypothetical situations, we used an online pandemic modeling simulator titled “Disease Epidemic Model” which utilized many different factors to create a model (Shodor, 2020). In our simulation, it is important to note that none of the included modeled universities took staff members into account (Figure 2). The simulations only model hypothetical situations for students. University staff is likely at the highest risk of contracting COVID-19, as members of older age groups and weakened immune systems have a much higher contraction, hospitalization, and mortality rate than the general population of college-aged students.

Table 1. University Student Populations at Different Capacities; Initial populations of enrolled undergraduate and graduate students at 100%, 75%, 50%, and 25% attendance, and number of doctors assigned to each university (Association of American Medical Colleges [AAMC], 2020; Harvard, 2020; University of Southern California [USC], 2020; Texas A&M University, 2020; University of Central Florida [UCF], 2020; Brigham Young University [BYU], 2020; Johns Hopkins University, 2020; Carnegie Mellon University, 2020; University of Alaska Southeast, 2020; Purdue University, 2020; Tulane University, 2020)

University	100%	75%	50%	25%	Doctors
Harvard University	36,012	27,009	18,006	9,003	81
University of Southern California	48,500	36,375	24,250	12,125	67
Texas A&M University	69,465	52,098	35,732	17,366	78
University of Central Florida	69,525	52,143	34,762	17,381	92
Carnegie Mellon University	14,799	11,099	7,399	3,699	23
Brigham Young University	33,511	25,133	16,755	8,377	36
Johns Hopkins University	23,917	17,937	11,958	5,979	46
Tulane University	12,646	9,484	6,323	3,161	16
University of Alaska Southeast	2,561	1,920	1,280	640	3
Purdue University	43,411	32,558	21,705	10,852	50

Another variable we accounted for in the simulation was the number of doctors that treat COVID-19 at every university campus, respectively. To do this, we used data from the Association of American Medical Colleges (AAMC) as to how many clinical physicians corresponded to every 100,000 people in each state (AAMC, 2019). We then used that number to estimate how many doctors corresponded to the population of college students on the specific campus we studied. We divided that number in half, as we estimated only about 50% of doctors would be treating the novel coronavirus if they had no other choice. Physicians such as optometrists, dermatologists, surgeons, and many other specialties, would not be treating COVID-19 patients, but it impossible to know exactly how many physicians in the United States are capable and willing to treat those ill with COVID-19, so we made an estimate that we simply held constant in each scenario for calculation purposes. These numbers aimed to provide a similar representative basis for each university, and may or may not be accurate or representative of each university. In addition, the model assumed that doctors cannot get sick. This is not the case; doctors fall ill from COVID-19 very frequently, due to exposure to the virus for long periods of time when treating patients. It is unlikely that all of the doctors would remain healthy in any scenario, but because the doctors were not considered to be part of the initial student population, if they had fallen ill, it would not have impacted our results in relation to each individual university. We thought it simply important to emphasize that this model does not perfectly adjust to realistic situations.

Additionally, the simulation we utilized had the ability to section off parts of our hypothetical campuses to limit travel to certain degrees. We chose not to include any barriers because we did not want to create unknown variables. This is because students do not have the same probability of interacting with any other given person on campus at any given time (due to major and minor classes structure, living situation, friend groups, and many other variables), and it is impossible to know how many of these situations exist in one college campus. Hence, the simulation models the situation in which any one person has an equal chance of communicating or interacting with any other student on campus at a given time. This may change the risk of contraction by an unknown amount, because in this situation, the disease can spread to everyone on campus and doesn't take into account the different living situations and interactions of students at a given university in a completely closed campus.

Furthermore, within the model we accounted for a 3.7% infectiousness, as it was found that wearing masks reduces the risk of infectiousness from 17.4% to 3.7% (Dier, 2020). All universities that we studied and addressed it require all students, staff, and visitors to wear masks at all times upon return in the fall, unless the individual is alone in an office, or social distancing outside. It is not a guarantee that every student will follow these guidelines at all times, so it is likely that the infection rate will be slightly higher in reality. However, on a scale of 1-100%, we included an additional 15% of safety measures under the category of prevention and treatment, which held constant for each university. This was to account for the plans for the universities to clean high touch surfaces, some students and staff wearing additional PPE (Personal Protective Equipment), but also assuming that some students do not abide by the safety guidelines. Even though each university plans to implement different safety guidelines, it is hard to know how effective those will be at each school, so we chose to keep the prevention and treatment the same for all of them, in addition to including an infectiousness that assumes everyone wears a mask.

Additionally, we made sure not to account for a vaccine or successful medication into this model because both will likely not be readily available for COVID-19 by fall 2020. However, if such treatment is made available by this coming fall, it is likely that both cases and mortality rates would take a sharp decline.

In the "Days to Recover" variable, we implemented a 14 day average. In some situations it would take more or less than that time frame for a patient to recover, but, 14 days is the average length of recovery time for COVID-19. (Centers for Disease Control and Prevention [CDC], 2020)

Under the "fatality rate" setting, we used a rate of 0.121% (Berezow. 2020). This is the fatality rate for people in the age groups of 18-24 years old. Many graduate students fall out of that age range, and hence have an even higher mortality rate. Because ages of graduate students were unavailable for each university, we assumed the calculated death rate for the ages 18-24 would be accurate enough for our modeling purposes, but the potential death rate could be higher depending on the ages of the students at each university.

By implementing all of these variables for each university, we ran the simulation for 120 days to see how the hypothetical COVID-19 cases would spread. We found that within larger universities and with larger populations of students, the virus spread much more quickly. A university campus was simulated within the model, showing how many people were doctors in the situation (white figures), healthy (green figures), infected (red figures), or immune (blue figures). The fatalities were removed from the campus model.

For each day of the simulation, we recorded the ongoing cases during that day, the number of recovered and immune patients, and the number of ongoing deaths for each of the four capacity totals at each university. With all of that retrieved data, we created graphs and charts to illustrate the data in a different format, including 3 different graphs for each university (Appendix A). The first showed the ongoing cases, with four different lines representing cases at 100, 75, 50, and 25 percent capacity. The next showed ongoing deaths with the same four lines representing the different capacities. The last showed the ongoing immunities, also with the four representational lines.

Ten colleges were included in this case study (Table 1), including one college from each of the states with the most number of new cases per day as of July 23, 2020; Florida, Texas, and California.

It is important to recognize that this model does not account for how quickly or how well the virus is spreading in the college's surrounding county or state. The infection rate is based solely on the global average, and not on regional averages for each university. This could result in actual numbers being different than those simulated. In addition, in many situations there is likely to be more than one student entering campus with the virus. This simulation is only intended to model the effects of if just one student with COVID-19 were to come onto campus upon reopening. The impacts of several initial infections have not been accounted for, but would almost certainly be much more serious.

In testing our research question, we used an online epidemiological simulator software to model the spread of COVID-19 throughout college campuses across the US. This simulator allowed us to enter the student population of each university (which we altered depending on the attendance rate we tested, 100%, 75%, 50%, and 25%), and the number of doctors relative to each university, which we calculated using AAMC data on the number of practicing physicians in the state each university was located in. The simulator also allowed us to input relevant constant variables that would make an impact on the spread of COVID-19, such as the limits on travel (we chose to use 0 limits on travel in our model), the overall sanitation of the university (which we kept at a constant 15/100), infectiousness (3.1%), average days to recover (14 days), and fatality rate for this age group (0.121%). After correctly setting up the simulator, we ran it 40 times (once for every one of the 10 universities tested for each of the attendance rates, see results below in the *Results* section and in Appendix A) and collected the data each time. Lastly, we created tables and graphs to analyze and visualize our data.

4. Results

We hypothesized that as the number of students colleges allow on campus increases, the number of semester COVID-19 cases will increase exponentially. To test our hypothesis, we used the "Disease Epidemic Model" by Shodor to predict the number and spread of COVID-19 cases at each university. ("Disease Epidemic Model," 2020). In order to use the model, we had to plug in specific values that concerned the student population of each university and statistics that describes the virality, fatality, etc. of COVID-19. We ran simulations for each university, then downloaded the results from the simulator and created tables and graphs that represented the data using Google Data Studio. The first 5 days and last 5 days' predicted numbers of cases, deaths, and immunities are listed in Appendix B (Tables 3-32).

For the larger universities (University of Southern California, University of Central Florida, Texas A&M University, Purdue University, Brigham Young University, Harvard University and Johns Hopkins University to some extent), it looks as though our hypothesis was correct, as in all of our tables and graphs, an exponential curve can be seen in the number of COVID-19 cases as the percent attendance increases steadily/linearly. However, in the smaller universities (including Tulane University, University of Alaska Southeast, and Carnegie Mellon University), the exponential curve is much less accentuated, and is nonexistent in the smallest of those three, the University of Alaska Southeast. This is presumably because the model interprets these universities to be less dense in population, accounting for less interactions among students and less rise of COVID-19 cases.

Using the predicted data shown in the tables above from the simulator, the reopening of large universities at any attendance level (100%, 75%, 50%, or 25%) will likely lead to a surge in the number of COVID-19 cases that will overwhelm the healthcare system and inevitably lead to some student deaths. Looking at Harvard's predicted COVID-19 spread; if just one infected person were to come to the university, it becomes clear that at any level of attendance, there would inevitably be some deaths. In addition, our model is potentially a best case scenario, as it doesn't take into account the existing COVID-19 cases in the city, county, or state the university is located in, and it represents a situation in which only one student comes to campus infected. In reality, it is likely that more than one case 0 is to be expected on return to each campus, particularly on the campuses of the larger universities. As for smaller universities, such as the University of Alaska

Southeast, Tulane University, and Carnegie Mellon, the expected impact of reopening on COVID-19 cases is not so drastic. Rather, at each of these universities, there are no predicted COVID-19-related deaths for reopening at 75%, 50%, and 25% attendance.

This may not mean, however, that it is entirely safe for these universities to reopen, as our model does have some inaccuracies that impacts its results, and everything predicted by the model is subject to chance. These inaccuracies include the assumption that student population density uses the total student population number as a gauge for it. Campuses where students are more spread out (lower population density) may be less reliant on the actual population numbers of the campus to predict how the disease spreads. Our model also assumes that each university is a closed campus, and that no one can exit the campus and come back infected. Therefore, the model predictions could lead to results that are higher or lower than actual expected COVID-19 cases and deaths, so even though smaller campuses are at a much lower risk of having a high number of infections, other unaccounted for factors and variables, in addition to omnipresent chance, could lead to significantly different results in Fall 2020.

It is important for all colleges to evaluate all of the potential risks and benefits of returning to school, and at what allowed attendance of students. It is understood that moving to online education puts the universities in dangerous financial situations, puts the students in a far more suppressive learning environment, and creates many times more academic integrity risks; however, it does preserve the students' safety to the maximum amount (Wood, 2020). By using data visualizations that depict full data sets (Appendix A), parts of which are shown below in Appendix B (Tables 3-32), we saw an indication that opening at 25% attendance would be relatively the safest option, with the least number of cases projected of all the simulations. At 25% attendance, 475 cases was the highest number predicted (predicted for Texas A&M, Table 7) for any of the ten universities studied, more than quadruple the next largest predicted number of cases at this percent capacity, which was 93 cases.

Moving from 25% to 50% of the student population on campus causes significant increases in cases and potential deaths, but not nearly as much as the increases between allowing 50% and 75% of the population back on campus. For instance, the predicted cases at Harvard University (at 25% attendance) by the end of the semester (120 days) increase by 42 times when increasing to 50% attendance. However, this is small when compared to the increase in cases from 25% to 75% attendance, which is a greater than 108 times the 25% projection (Table 1).

A similar, but less drastic increase difference is represented in Harvard's death rate (Table 4), as there are no projected deaths at 25% capacity, but the toll rises to 4 at 50%, and then to 13 at 75%. It sharply increases again if you were to introduce the entire population back to campus, with 25 projected deaths at Harvard by the end of the Fall term. Most of the other universities we studied emulate a similar pattern, some to an even greater degree, such as the University of Southern California and Texas A&M University.

At Johns Hopkins University (JHU), there are no projected deaths until 75% attendance (Table 20); insinuating that introducing a population of up to 50% could potentially be an acceptable number of students to have on campus. However, at the second largest campus studied, Texas A&M, even at 25% of total enrollment, 3 deaths were predicted by the simulation (Table 8). The University of Central Florida projects 2 and 21 deaths at 25% and 50% attendance respectively, which are dangerously high predictions for so little of the overall student population being allowed on campus. This has caused us to conclude that for larger universities especially, maximum safety requirements must be enforced at all times, with many doctors and hospitals available if universities so choose to have any fraction of students on campus, and they should not consider allowing any more than 25% of their total undergraduate and graduate enrolled students to come on campus if they value the health and safety of their student population.

A general pattern can be seen among all of the projection graphs other than Brigham Young University, Johns Hopkins University, the University of Central Florida, and the University of Alaska

Southeast (Appendix A), in which the difference in cases between 50% and 75% is incredibly dramatic, indicating that as a general case, maintaining a campus population of 50% of the total population enrolled is the maximum amount of students that should be allowed on campus to intermingle. This is not subjective, and as studied, each university and size will have to adjust to projections accordingly. However, bringing anywhere near to 100% of the full student population back to campus is an unsafe decision at most universities, with 7 of the 10 universities studied having over 10 projected deaths with most of their student body back on campus. Based on our model predictions (Appendix A), full attendance could be safe only at very small schools, such as those with 15,000 enrolled students and fewer (those studied include Tulane University, Carnegie Mellon University, and the University of Alaska Southeast; Tables 14, 23, and 26). This is because 1 or fewer deaths are projected at each while at 100% attendance. 1 is still a significant number, so if universities of these sizes decide it is safe to return at such high numbers, they still must follow maximum safety precautions, and maintain high observance and restriction to their student populations.

It is important to note that all graphs and charts of every university's case study, other than the University of Alaska Southeast, show an increase in cases, deaths, and immunities, as the percentage of students allowed on campus increases by the end of the semester. As the days draw closer to the end of the semester, there are no overlapping lines, (with the lines representing each of the four measured percent attendances; see Appendix A), and as the percent attendance increases, their corresponding graph lines reach higher. This is indicative of a highly positive correlation between the number of students who are allowed on campus and the number of cases of COVID-19 that would occur, and the number of deaths and immunities that would result because of the number of cases. Universities must be aware of the fact that the greater the student population they introduce to campus, no matter how seemingly insignificant, the greater the risk of contracting COVID-19 for each individual on campus.

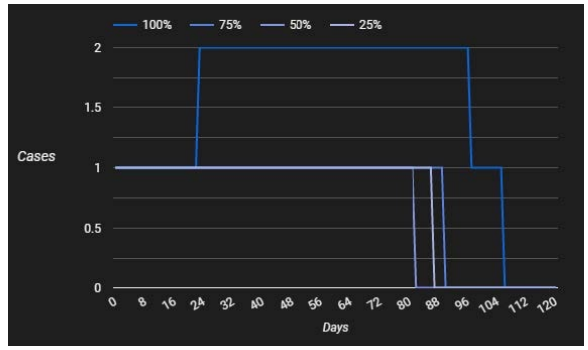

Figure 2. Projected COVID-19 cases at the University of Alaska Southeast: Graph depiction of predicted COVID-19 cases at the University of Alaska Southeast at each percent attendance (Appendix A contains more details)

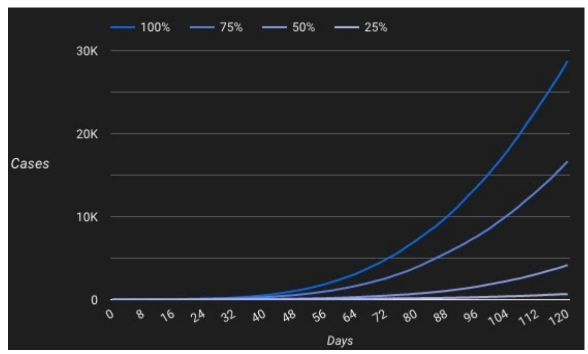

Figure 3. Projected COVID-19 cases at the University of Central Florida; Graph depiction of predicted COVID-19 cases at the University of Central Florida at each percent attendance (Appendix A contains more details)

The only graph and data depiction (Tables 25, 26, 27) that seemingly contradicts this positive correlation is the data for the University of Alaska Southeast (Cases graph depicted below in Figure 3). Although there are never any deaths, increasing the population on campus does have a positive correlation with the number of cases, as at 100% of their enrolled population returning, the projection reaches 2 cases at one time, as opposed to 1 at all other population amounts measured. This data is relatively insignificant however, because we worked with a projection that only estimates the spread of the disease, and 1 case is not enough to show a valid pattern for this university. This data does indicate that at very small schools, one case of the virus is often likely to get treatment fairly quickly and not infect any or many other people. This leads us to conclude that at smaller universities (and in particular the University of Alaska Southeast where there are very few cases of coronavirus in general), there is a much lower risk of spreading COVID-19 even at 100% attendance, which may indicate that it is safer for smaller universities to return to school at relatively higher attendance percentages than larger universities (Figures 3 and 4; model comparison of small and large university projected cases).

5. Discussion

In our research, we examined the projected impacts on COVID-19 cases, deaths, and resulting immunities in the event that various universities reopened at different capacities/attendance percentages (25%, 50%, 75%, and 100% attendance). Using a simulator by Shodor we modeled the spread and number of cases of COVID-19 in the university setting at these different attendance capacities and analyzed the results by creating graphs and tables to visualize the results of the simulations ("Disease Epidemic Model," 2020) (See Appendix A). Before we started running simulations, we hypothesized that as the number of students colleges allow on campus increases, the number of semester COVID-19 cases will increase exponentially. Our hypothesis was correct in the context of the larger universities, as a clear exponential increase was observed when increasing the universities' attendances by even as little as 25%. These results can also be seen in Appendixes A and B. However, for smaller universities that had fewer than 15,000 students, our hypothesis was less observable, but still proven correct. The only outlier was the University of Alaska Southeast, which had no predicted deaths at any of the attendance levels, and only 2 projected cases, even at 100% attendance. We concluded that no valuable and/or legitimate correlations could be drawn from the models for this university because there were so few cases and no pattern could be seen, and so we determined that in similarly small environments the virus would likely just filter out considerably quickly and affect a very small number of people.

By looking at the predicted COVID-19 cases using our models generated by the simulator, we were able to conclude that it will likely be safer for smaller universities to return to campus in-person at a higher attendance (75%-100%) because there were far fewer cases and deaths resulting from a lower spread of the virus. In contrast, for larger universities, we concluded that it would be much more dangerous to return to campus in-person, especially at higher attendances. At such larger universities, a much more eminent exponential curve was observed when comparing higher attendance percentages to the number of COVID-19 cases. Even at 25% attendance, with the set conditions, these universities would inevitably have some deaths, which makes it particularly unsafe to return to campus with large amounts of students, and indicates that very strong measures and restrictions such as those modeled by Taiwan are a must for larger schools; everyone who returns is at a higher risk of contracting and spreading COVID-19, and those dangers must be met with more precautions. Given this data, it is imperative to recall the drawbacks and inaccuracies of our model, such as that it did not take into account the existing number of cases in the surrounding area of the university, the number of doctors may not have been completely accurate due to that we used state averages that will inevitably differ for each area of the state, and that our model used student population as a gauge for population density and interactions among said population, which is not always the case for different sized universities. In addition to this, our model was merely a prediction and will never represent the exact number of cases and spread of COVID-19 cases in a campus, as everything is subject to random chance in this situation.

As universities begin to reconsider their choices in reopening schools, our research becomes incredibly relevant in making important decisions that may impact the spread of COVID-19 not just throughout the university, but also the surrounding community that the university is a part of. Universities must weigh all the risks and benefits of reopening schools at different sized capacities in order to make informed decisions that will keep their students, faculty, and surrounding community safe from COVID-19. Our models and past precedent both indicate that even as few as 10 cases could result in a much greater spread of COVID-19, not just to college-age students with healthy immune systems, but to their professors, their families, their friends, and the immunosuppressed whose bodies will not handle COVID-19 in the same way. The decision of whether to accept students' full tuition costs by allowing them to stay on campus this coming fall, despite the apparent risk of them contracting, spreading, and dying from COVID-19 examined in our models is entirely up to the universities, but we hope that our conclusive data may shed light on the potential dangers of reopening, in particular with full or near to full attendance from students. Looking at past data from the COVID-19 outbreak in Taiwan and other countries, it is clear that when even a few cases arise, safety precautions such as cancelling classes for weeks at a time must be taken in order to ensure safety of all students and faculty and to prevent the spread of the disease (Cheng, 2020). Universities' decisions of whether they are willing to lose part of their profits to ensure the health of their students and faculty will certainly help to determine the future spread of COVID-19 in the US, and so we hope that our research will allow them to make the most educated ones possible.

Given our hopes of helping universities make more informed decisions, we recognize our research only highlights a few major aspects when it comes to epidemiological modeling of the distribution and spread of communicable diseases like COVID-19. Our model had several limitations as formerly discussed,, and there may exist a simulator or software that would more accurately depict the spread of COVID-19 and other similar diseases. Other than guaranteeing or disagreeing with our prediction models, future research should run simulations to determine what would happen if more people initially entered the university infected, in order to see the spread of COVID-19 in various instances in the individual university campuses. The simulator we used also did not allow us to account for the number of COVID-19 cases in the surrounding area of the university, the population demographics, or the density of the surrounding area, all of which would impact how the virus is likely to spread among the campuses. Looking into this variable of how COVID-19 may spread would help to make more accurate predictions, as we only examined what would happen in a closed campus setting with few limits on student interaction with one another. Open campuses, especially those located within large cities, allow for more interaction with the surrounding people and city, and therefore would presumably spread COVID-19 faster.

A study with more case studies within it may create a more accurate prediction of the spread of COVID-19 in more situations, but due to time constraints we chose to study 10 universities of various sizes and locations so as to represent a wide array of learning environments that COVID-19 could affect differently if introduced to each campus. Most universities are also considering inviting students back to campus, but with many of their classes online. A future study should evaluate to what degree partially online school helps to stop the spread of the virus. An additional idea for future research would be to alter different variables on the simulator we used, such as the level of sanitation (which we kept at a constant 15/100 for all simulations) or the limits on travel (which we left unchecked and set to 0 for all simulations) to evaluate how each would impact the spread of COVID-19. In how we used the simulator we were unable to account for the staff on campus, who are at the highest risk of infection and death from the virus. It is critical that the dangers to staff and professors on campus are also evaluated before universities make decisions on how to implement learning in the fall. Accounting for the staff and examining how they would be affected in these instances would be valuable research to add to this quickly evolving field of study, and would help many universities come to a final and conclusive decision on their future plans, long anticipated by those enrolled and their families.

5.1 Review of Universities' Reopenings in Fall 2020

As universities were forced to adapt as a result of the COVID-19 crisis in the 2020-2021 school year, changes throughout every level of their educational structures occurred. Over 1,300 colleges and universities moved to hybrid or fully online formats, as the typical in-person classes and labs were cancelled in the Spring of 2020, and by the fall, only

27% of schools were planning to offer fully or mostly in-person classes (Smalley, 2021).

As described by a survey taken by the U.S. Census Bureau of college students in Fall of 2021,

- 15 million indicated their institution changed the content or format of classes. Among these:
- 9 million indicated this did not affect their plans for school in the fall
- 4 million indicated all plans to take classes had been canceled
- 2 million indicated classes would be different formats in fall
- 8 million indicated fewer classes would be taken
- 201,281 indicated more classes would be taken
- 709,132 indicated classes would be taken from a different institution
- 574,237 indicated classes would be taken for a different certificate or degree (Hanson, 2021)

Of note, the majority of universities saw declines in attendance rates, as students chose to drop out and defer as a result of COVID-19. Private for-profit colleges were 180 million cases worldwide with 3.91 million deaths attributed to COVID-19. The vast spread of the virus made it almost impossible for larger universities to continue to hold majority in-person classes throughout the 2020-2021 school year. The online and alternative formats to in-person classes created additional problems such as the major drops in enrollment, particularly within black and low-income communities (St. Amour, 2020), as well as massive mental health issues worldwide, higher suicide rates, and dropping grades in all types of schools. The only grouping to see an increase in enrollment, undoubtedly as a result of their generally smaller population size and easier containment measures. In general, smaller colleges, unsurprisingly those with 15,000 students or less, were much better off than those with larger student populations (Figure 5). Note in said figure how every other grouping of colleges and universities suffered losses in enrollments during 2020.

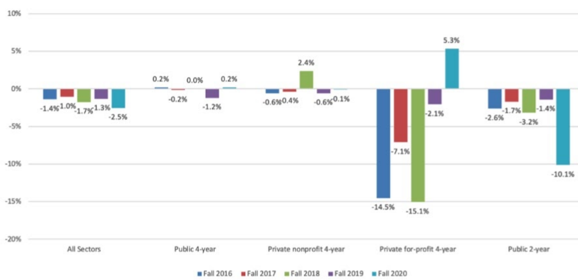

Figure 4. Penchant Change in Enrollment form Previous Year by Institutional Sector:2016 to 2020. Shown is the change in enrollment for each sector of college/university: Most notably is the comparison between the enrollment rates of private schools before and during 2020, and the notable surge in 2020 enrollment, as well as the decrease in enrollment overall (St. Amour, 2020).

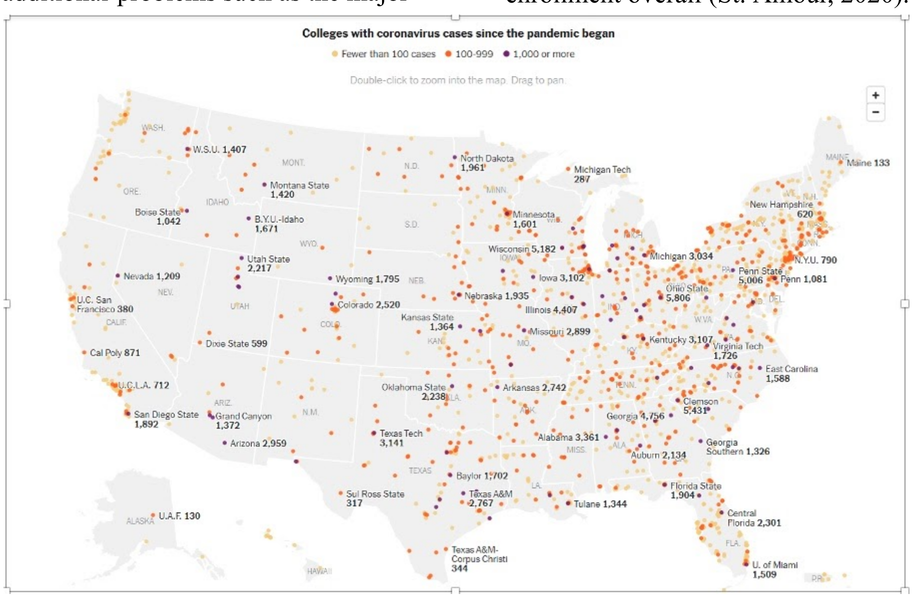

Figure 5. Colleges with Coronavirus Cases Since the Pandemic Began. A depiction of all of the known college cases across the US by school as of December 11, 2020. (New York Times, 2020)

By June 26, 2021, there had been 180 million COVID-19 cases worldwide with 3.91 million deaths. "More than 85 colleges have reported at least 1,000 cases over the course of the pandemic, and more than 680 colleges have reported at least 100 cases." By December 11, 2020, there had been over 397,000 cases among college students in over 1,800 colleges (New York Times, 2020). In Figure 5 is shown the severity of colleges across the United States, including but certainly not limited to those in our case study. As depicted, thousands of colleges saw massive case numbers, as the map lights up in colorful dots across the nation. The Midwest and east coast saw the highest hotspots of cases within college-aged students, seen by the concentration of cases within the schools.

By Spring of 2021, the vast majority of surveyed universities were still not holding classes in a traditional classroom and college setting, and many of those who began the year entirely in person, had quickly been forced to send students home or online.

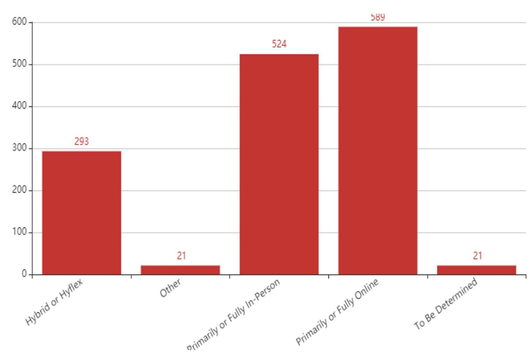

Figure 6. Spring Plans 2021. In a survey of 1,448 colleges and universities, this histogram depicts which learning format would be instantiated in the Spring semester of 2021. This is related to, but not indicative of the learning formats instantiated in the prior Fall semester (Davidson College, 2021).

As indicated by Figure 6, within the surveyed colleges and universities only ~36% were planning to return to a normal setting by the Spring semester. Of those returning fully in person, it was generally smaller universities who were able to do so, due to easier containment, contact tracing, sanitation measures, and enforcement of safety protocols. A prime example of a larger university who had to send students back home was the University of North Carolina at Chapel Hill-within 2 weeks of admitting all students back to campus in the Fall, sent almost all back home to a virtual setting, after seeing an immediate surge in COVID cases. Almost every campus who had students on campus during the pandemic had to establish containment wards for exposed and infected students, where individuals had to isolate themselves and quarantine.

Few universities' complete fall 2020 reopening plans are fully available to the public, and each university recorded their student cases differently for the semester (some provided combined faculty and student cases, and Harvard University did not have data for only Fall 2020). As a result, the chart below estimates the reopening capacity (based on the closest prediction of our model) of universities that did not provide exact data on their reopening capacities. These universities are denoted with an asterisk (*) next to their reopening capacity. The rightmost column of the chart shows what our model predicted the number of cases to be, for the most similar capacity of students returning to the amount that actually returned (or the most similar number of cases for universities that did not provide data on their Fall 2020 reopening capacity). For five out of the ten universities studied, we found that our model prediction fell within a 25% range of the actual number of students that contracted COVID-19. Rather than looking at the size of a university to predict the number of COVID-19 cases, we believe that a more accurate predictor of its future cases were things that cannot be quantified in statistical models- such as the measures taken to slow the transmission of COVID-19, and how strictly they were enforced. Regardless, the recommendations we made to universities' reopening were generally accurate to the universities' Fall 2020 reopening plans, with the exception of larger universities such as Texas A&M University and Brigham Young University. As noted in Table 2 below, there was certainly a positive correlation between how many students were allowed back on campus, and the number of COVID-19 cases that occurred. In addition, the results of total reported cases generally reflect numbers similar to those predicted using our Shodor model under similar circumstances.

Table 2. Universities' actual COVID-19 cases for Fall 2020 vs. our model's prediction of cases

University	**Fall 2020 Reopening Capacity**	**Number of Cases**	**Our Model Prediction**
Harvard University	3.89%	388 (total undergraduate and graduate student cases as of June 20, 2021)	15 cases (25% capacity)
University of Southern California	9.25%	613 total undergraduate and graduate student cases in fall 2020	28 cases (25% capacity)
Texas A&M University	75%*	4,890 cases in fall 2020 (w faculty included)	4695 cases
University of Central Florida	42.71%	2622 cases	2059 cases (50% capacity)
Carnegie Mellon University	75%*	29 cases	21 cases
Brigham Young University	100%	3,634 cases in fall 2020 (w faculty included)	2718 cases
Johns Hopkins University	50%	105 cases	107 cases
Tulane University	100%*	1381 cases	53 cases
University of Alaska Southeast	100%*	2 cases	2 cases
Purdue University	50%*	684 cases	302 cases

6. Conclusion

As COVID-19 cases continued to rise in the US, universities' fall 2020 reopening plans became increasingly complex and ambiguous- while some colleges planned to move to a hybrid or virtual format, the majority had opted for a completely in-person plan that disregards the value of the health of their own students, faculty, and cities, for personal gain and profit, and with the understanding that in-person is the best way to educate.Although this is true, more factors must be evaluated before such decisions can be made, and therefore in our study, we examined how altering the in-person attendance rate of ten universities of different sizes and locations would impact the spread and number of cases of COVID-19. To conduct our study and test our hypothesis, we used an epidemiological modeling software by Shodor to model our data for each of the universities in each of the different scenarios (100%, 75%, 50%, and 25% attendance) ("Disease Epidemic Model," 2020). Keeping all other variables constant other than the population size, we found that as the in-person attendance grew linearly for each of the universities, we observed an exponential growth in the number of COVID-19 cases at each university, especially in the larger universities, leading to as many as 76 deaths (at Texas A&M University at 100% attendance, see Appendix B, Table 8). This pattern was visible in all universities other than the University of Alaska Southeast, where no pattern could be observed because of the low number of cases resulting from the small size of the university. Therefore, we can conclude that it is not safe for most universities to go back to in-person classes and residence life at full attendance, as this would likely cause a surge in the number of COVID-19 cases that would result in a positive feedback loop in which the disease spreads at an exponential rate. For larger universities such as the University of Central Florida and Texas A&M University, even going back at 25% capacity is anticipated to result in a few deaths (see Appendix B, Tables 8 and 11); contrarily, smaller universities like the University of Alaska Southeast and Carnegie Mellon University could supposedly go back at full attendance and experience minimal cases and COVID-19-related deaths. It is important to keep in mind that even though our models of these universities may predict no deaths, it does have inaccuracies and there will still be a small chance of death for any given individual that is on-campus and contracts the virus. In order to combat COVID-19, universities need very strict safety measures in order to pose the least risk to their students, faculty, and community, similar to those enforced in Taiwan (Cheng, 2020) and Singapore (Melnick &

Darling-Hammond, 2020). To conclude, unless universities move to a completely online format, there will inevitably be a risk of contracting and spreading COVID-19 as universities choose to allow students to return to campus at any capacity. Formerly mentioned measures can be taken to reduce this risk, including reducing attendance and employing strict safety measures on campus (mandatory daily temperature checks, face masks, contact tracing procedures, etc), but in several situations, there is only so much people will be able to do at the university level to contain the spread, as there will always be those who don't follow the guidelines. The most foolproof method of reducing the spread of COVID-19 is to limit as many interactions as possible, and larger universities in particular should do this by only allowing a percentage of their enrolled population of students to return to campus in the Fall.

References

Association of American Medical Colleges. (2019). 2019 State Profiles. https://www.aamc.org/data-reports/workforce/data/2019-state-profiles

Berezow, A. (2020, June 25). Coronavirus: COVID Deaths in U.S. by Age, Race. American Council on Science and Health. https://www.acsh.org/news/2020/06/23/coronavirus-covid-deaths-us-age-race-14863

Brigham Young University. (2020). Facts & Figures. https://www.byu.edu/facts-figures

Carnegie Mellon University. (2019, September 16). University Enrollment by Degree Level. https://www.cmu.edu/ira/Enrollment/pdf/fall-2019-pdfs/fall-2019-university-total-enrollment.pdf

Centers for Disease Control [CDC]. (2020). Quarantine If You Might Be Sick. https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/quarantine.html

Centers for Disease Control [CDC]. (2020). Cases, Data, and Surveillance. https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/index.html

Centers for Disease Control and Prevention [CDC]. (2020). Mental Health and Coping During COVID-19. Center of Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/managing-stress-anxiety.html

Cheng, S., Center, H., Wang, C., Medicine, S., Shen, A., & Chang, S. (2020, July 12). How to Safely Reopen Colleges and Universities During COVID-19: Experiences From Taiwan. Annals of Internal Medicine. https://www.acpjournals.org/doi/full/10.7326/M20-2927?journalCode=aim

Covid-19 Information. "Harvard University-Wide COVID-19 Testing Dashboard." www.harvard.edu/coronavirus/testing-tracing/harvard-university-wide-covid-19-testing-dashboard/

Davidson College. (2021). C2i Dashboard. https://collegecrisis.shinyapps.io/dashboard/

Dier, A. (2020, June 03). Here's How Much a Mask Reduces Coronavirus Transmission. Newser. https://www.newser.com/story/291760/heres-how-much-a-mask-reduces-coronavirus-transmission.html

Domenico, L., Pullano, G., Sabbatini, C., Boëlle, P., & Colizza, V. (2020, January 01). Expected impact of reopening schools after lockdown on COVID-19 epidemic in Île-de-France. https://www.medrxiv.org/content/10.1101/2020.05.08.20095521v1

Harvard University. (2020). Harvard at a Glance. https://www.harvard.edu/about-harvard/harvard-glance

Jahanian, F., & Garrett, Jim. (2020, May 14). Our Path Forward. https://www.cmu.edu/leadership/president/campus-comms/2020/2020-05-14.html

Johns Hopkins University. (2020). Get The Facts: Undergraduate Admissions: Johns Hopkins University. https://apply.jhu.edu/discover-jhu/get-the-facts/

Johns Hopkins University (2020, June 30). Johns Hopkins announces plans for fall undergraduate experience. Johns Hopkins University Hub. https://hub.jhu.edu/2020/06/30/johns-hopkins-fall-2020-undergraduate-plans/

Johnson, E. (2020, June 23). BYU to hold in-person classes fall 2020. https://www.abc4.com/news/byu-to-hold-in-person-classes-fall-2020/

Melnick, H., Darling-Hammond, L., Leung, M., Yun, C., Schachner, A., Plasencia, S., & Ondrasek, N. (2020). Reopening schools in the context of COVID-19: Health and safety guidelines from other countries. Learning Policy Institute. http://www.nordcountryschool.org/uploads/5/2/3/3/5233925/1reopening_schools_covid-19_brief.pdf

Pana-Cryan, R., Ray, T., Bushnell, T., & Quay, R. (2020). Economic Security during the COVID-19 Pandemic: A Healthy Work Design and Well-being Perspective. Centers for Disease Control and Protection [CDC]. https://blogs.cdc.gov/niosh-science-blog/2020/06/22/economic-security-covid-19/

Protopsaltis, S., & Baum, S. (2019). Does Online Education Live Up To Its Promise? A Look At The Evidence And Implications For Federal Policy. George Mason University. http://mason.gmu.edu/~sprotops/OnlineEd.pdf

Purdue University. (2018). Student Enrollment, Fall 2018. Retrieved July 27, 2020, from https://www.admissions.purdue.edu/academics/enrollment.php

Purdue University (2020, July). Fall 2020 On-Campus Experience. https://protect.purdue.edu/students/campus-2020/

See, B., Wardle, L., & Collie, P. (2020, June 01). Teachers' responses to the school reopening strategy. Durham University. http://dro.dur.ac.uk/31047/

Sheikh, A., Sheikh, A., Sheikh, Z., & Dhami, S. (2020, June). Reopening schools after the COVID-19 lockdown. National Center for Biotechnology Information. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7321012/

Shodor. (2020). Disease Epidemic Model (2020). http://www.shodor.org/featured/ASLDiseaseModel/model

Smalley, A. (2021, March 22). Higher Education Responses to Coronavirus (COVID-19). https://www.ncsl.org/research/education/higher-education-responses-to-coronavirus-covid-19.aspx

St. Amour, M. (2020, December 17). Final fall enrollment numbers show pandemic's full impact. https://www.insidehighered.com/news/2020/12/17/final-fall-enrollment-numbers-show-pandemics-full-impact

Staff, C. (2020, July 27). Here's a List of Colleges' Plans for Reopening in the Fall. The Chronicle of Higher Education. https://www.chronicle.com/article/heres-a-list-of-colleges-plans-for-reopening-in-the-fall/

Texas A&M University. (2020). At a Glance - Texas A&M University, College Station, TX. https://www.tamu.edu/about/at-a-glance.html

The New York Times. (2020, August 26). Tracking the Coronavirus at U.S. Colleges and Universities. The New York Times. https://www.nytimes.com/interactive/2020/us/covid-college-cases-tracker.html

Tulane University (2020, June 17). SPHTM FALL 2020 Reopening Academic Plan. https://sph.tulane.edu/sites/sph.tulane.edu/files/SPHTM%20Fall%202020%20Semester%20draft%20plan%20061220%20%281%29.pdf

University of Alaska Southeast. (2020). University of Alaska COVID-19 Status. https://sites.google.com/alaska.edu/coronavirus/status?authuser=0

University of Central Florida. (2020). UCF Facts 2019-2020. https://www.ucf.edu/about-ucf/facts/

University of Central Florida. (2020, June 1). UCF Return to Campus Plan Fall 2020. https://www.ucf.edu/coronavirus/document/return-to-campus-plan/

University of Southern California. (2020). Facts and Figures. https://about.usc.edu/facts/

UNIVSTATS. (2020). Tulane University of Louisiana Student Population and Demographics. https://www.univstats.com/colleges/tulane-university-of-louisiana/student-population/

Williamson, L. (2020, May 24). Coronavirus: Why reopening French schools is a social emergency. British Broadcasting Corporation [BBC]. https://www.bbc.com/news/world-europe-52769626

Wood, G. (2020, April 28). There's No Simple Way to Reopen Universities. The Atlantic. https://www.theatlantic.com/ideas/archive/2020/04/co lleges-are-weighing-costs-reopening-fall/610759/

Worldometers. (2020, July 23). United States: Coronavirus. https://www.worldometers.info/coronavirus/country/us/

Young, M. K. A Thank You, Along With Plans For Summer And Fall. Texas A&M University, College Station, TX. https://www.tamu.edu/coronavirus/messages/april-30-thank-you-and-plans-for-summer-fall.html

Zukoski, C. F., & Wright, D. (2020, July 2). Letter on Student Housing and Course Schedules. USC Provost. https://www.provost.usc.edu/letter-on-student-housing-and-course-schedules/

Appendix A

[This links to a graphing tool where you can toggle between universities to see the projected number of COVID-19 cases and deaths & immunities associated with those cases]

Appendix B

Harvard University

Table 3. Predicted COVID-19 cases at Harvard University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	2	1	1
4	1	2	1	1
5	2	3	1	1
116	2417	1333	397	15
117	2490	1386	411	15
118	2542	1432	422	15
119	2610	1466	437	14
120	2705	1516	460	14

Table 4. Predicted COVID-19 deaths at Harvard University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	21	11	4	0
117	22	11	4	0
118	23	13	4	0
119	23	13	4	0
120	25	13	4	0

Table 5. Predicted COVID-19 immunities at Harvard University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	39	15	10	3
117	41	15	11	3
118	46	16	12	3
119	49	18	12	4
120	52	20	12	4

University of Southern California

Table 6. Predicted COVID-19 cases at University of Southern California by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	2	1	1	1
4	2	1	1	1
5	2	1	1	1
116	4556	1974	150	25
117	4655	2040	159	26
118	4771	2112	170	26
119	4894	2177	178	28
120	5027	2247	181	28

Table 7. Predicted COVID-19 deaths at University of Southern California by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0

116	49	24	1	0
117	51	24	1	0
118	52	24	1	0
119	53	24	2	0
120	54	24	2	0

Table 8. Predicted COVID-19 immunities at University of Southern California by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	71	11	1	1
117	77	11	1	1
118	84	12	1	1
119	91	13	1	1
120	98	16	1	1

Texas A&M University

Table 9. Predicted COVID-19 cases at Texas A&M University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	2
5	1	1	1	2
116	5866	4153	576	423
117	6026	4292	601	438
118	6187	4411	624	457
119	6349	4545	653	467
120	6506	4695	687	475

Table 10. Predicted COVID-19 deaths at Texas A&M University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	52	39	5	3
117	53	41	5	3
118	54	42	5	3
119	58	43	5	3
120	61	45	6	3

Table 11. Predicted COVID-19 immunities at Texas A&M University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	45	65	2	9
117	56	69	2	10
118	62	78	2	10
119	73	82	2	10
120	86	85	2	10

University of Central Florida

Table 12. Predicted COVID-19 cases at University of Central Florida by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
116	6215	3959	1806	81
117	6370	4081	1848	83
118	6544	4204	1916	86
119	6729	4319	1979	91
120	6917	4417	2059	93

Table 13. Predicted COVID-19 deaths at University of Central Florida by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0

3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	68	44	21	2
117	69	44	21	2
118	72	48	21	2
119	73	50	21	2
120	76	50	21	2

Table 14. Predicted COVID-19 immunities at University of Central Florida by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	59	34	14	4
117	69	35	16	4
118	74	38	19	4
119	84	43	19	4
120	96	51	21	4

Carnegie Mellon University

Table 15. Predicted COVID-19 cases at Carnegie Mellon University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	0	2	1	1
3	1	2	1	1
4	1	2	1	1
5	1	2	1	1
116	58	18	4	0
117	61	20	4	0
118	63	20	4	0
119	69	21	4	0
120	75	23	4	0

Table 16. Predicted COVID-19 deaths at Carnegie Mellon University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	1	0	0	0
117	1	0	0	0
118	1	0	0	0
119	1	0	0	0
120	1	0	0	0

Table 17. Predicted COVID-19 immunities at Carnegie Mellon University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	1	3	1	1
117	1	3	1	1
118	1	3	1	1
119	1	3	1	1
120	1	3	1	1

Brigham Young University

Table 18. Predicted COVID-19 cases at Brigham Young University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	2	1	1	1
2	2	1	1	1
3	2	1	1	1
4	3	1	1	1
5	3	1	1	1
116	2438	725	330	21
117	2495	751	336	21
118	2574	780	347	22
119	2639	813	354	22
120	2718	844	367	22

Table 19. Predicted COVID-19 deaths at Brigham Young University by day at each percent attendance

Days	100%	75%	50%	25%

0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	20	9	1	0
117	21	10	1	0
118	21	11	2	0
119	21	11	2	0
120	21	11	2	0

Table 20. Predicted COVID-19 immunities at Brigham Young University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	30	7	5	6
117	36	7	6	6
118	40	8	6	6
119	46	9	6	6
120	53	10	6	7

Johns Hopkins University

Table 21. Predicted COVID-19 cases at Johns Hopkins University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
116	781	178	91	0
117	813	180	97	0
118	845	188	102	0
119	869	195	103	0
120	910	203	107	0

Table 22. Predicted COVID-19 deaths at Johns Hopkins University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	11	1	0	0
117	11	1	0	0
118	11	1	0	0
119	11	1	0	0
120	11	1	0	0

Table 23. Predicted COVID-19 immunities at Johns Hopkins University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	7	4	5	1
117	10	4	5	1
118	10	4	6	1
119	11	4	7	1
120	11	4	7	1

Tulane University

Table 24. Predicted COVID-19 cases at Tulane University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	2	1	1
4	1	2	1	1
5	1	2	1	1
116	42	33	3	3
117	46	34	3	3
118	46	34	3	3
119	51	35	3	3

120	53	38	3	3

Table 25. Predicted COVID-19 deaths at Tulane University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	1	0	0	0
117	1	0	0	0
118	1	0	0	0
119	1	0	0	0
120	1	0	0	0

Table 26. Predicted COVID-19 immunities at Tulane University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	3	3	2	1
117	3	3	2	1
118	3	3	2	1
119	3	4	2	1
120	3	4	2	1

University of Alaska Southeast

Table 27. Predicted COVID-19 cases at University of Alaska Southeast by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
116	0	0	0	0
117	0	0	0	0
118	0	0	0	0
119	0	0	0	0
120	0	0	0	0

Table 28. Predicted COVID-19 deaths at University of Alaska Southeast by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	0	0	0	0
117	0	0	0	0
118	0	0	0	0
119	0	0	0	0
120	0	0	0	0

Table 29. Predicted COVID-19 immunities at University of Alaska Southeast by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	2	1	1	1
117	2	1	1	1
118	2	1	1	1
119	2	1	1	1
120	2	1	1	1

Purdue University

Table 30. Predicted COVID-19 cases at Purdue University by day at each percent attendance

Days	100%	75%	50%	25%
0	1	1	1	1
1	1	1	1	1
2	1	2	1	1
3	2	3	1	1
4	2	3	1	1
5	2	4	1	1

116	3424	2397	250	29
117	3534	2467	262	33
118	3634	2530	274	35
119	3737	2604	288	35
120	3825	2677	302	35

Table 31. Predicted COVID-19 deaths at Purdue University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	37	21	5	0
117	41	22	5	0
118	42	23	5	0
119	44	23	6	0
120	46	24	7	0

Table 32. Predicted COVID-19 immunities at Purdue University by day at each percent attendance

Days	100%	75%	50%	25%
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
116	20	41	3	3
117	22	45	3	3
118	24	51	3	3
119	27	55	3	3
120	29	59	3	3