COVID-19 and the Impacts to K-12 Schools
Bala Consulting Engineers COVID-19 Task Force
June 16, 2020 *(updates will follow as necessary)*

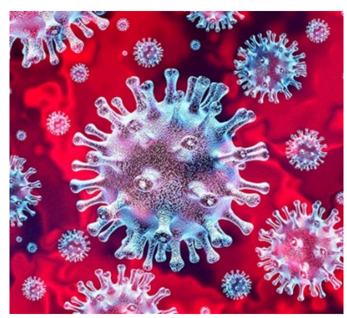
This report is a continuation of our research on COVID-19 and how it impacts facilities across all market sectors. This paper focuses on strategies and recommendations for K-12 educational facilities, as well as some general information on the COVID-19 virus and building systems recommendations that are applicable for many types of facilities.

EXECUTIVE SUMMARY

Schools in the K-12 market face unique challenges in preparing their facilities for the return of students, teachers and staff. The diversity of space types and systems require a number of different solutions and strategies to improve the environment, reduce common touch points and distribute the people. School officials are also tasked with addressing the k-12 school guidelines released by the health officials and state and local governments, as well as addressing safety concerns from parents. To maintain a productive learning environment schools can implement strategies to improve air quality, provide touch-free plumbing fixtures and door operations as well as increase daily cleaning procedures and reconfigure spaces.

Bala has researched and consulted with industry leaders in education, government agencies and health experts to present some of the most effective ways to make education buildings safer. This research continues as the data and knowledge on COVID-19 evolves. We will update this report when we have new information to share.

THE VIRUS



COVID-19 (or 2019-nCoV), as named by the World Health Organization (WHO), is the disease caused by the new coronavirus that emerged in China in December 2019. COVID-19 is caused by the SARS-CoV-2 virus. As a result, parallels are being drawn between the 2003 SARS outbreak and the spread of COVID-19.

Researchers know that the new coronavirus is spread through direct contact with an infected person or by touching a surface or object that has the virus on it and then touching your eyes, nose, or mouth. It can also be spread through larger droplets released into the air when an infected person coughs, sneezes or talks.

According to a new study from National Institutes of Health, CDC, UCLA and Princeton University scientists in The New England Journal of Medicine, scientists found that severe acute respiratory syndrome coronavirus (SARS-CoV-2) was detectable for up to three hours in aerosols, up to four hours on copper, up to 24 hours on cardboard and up to two to three days on plastic and stainless steel. The incubation period (or when symptoms appear) is within 14 days of exposure. As a result, staff, faculty and students can be in the school without knowing they are infected, contagious or have been exposed to the virus. Additionally, new research from China indicates that the novel coronavirus is also spread by fecal-oral transmission.

HVAC SOLUTIONS

The diversity of spaces found within a school present unique challenges and solutions. Controlled access, separation and cleaning represent some of the primary defenses against the spread of the virus. In addition, protections may be applied to existing and new HVAC systems to minimize further spreading of the virus within our schools. The following chart presents spaces, their typical-HVAC systems and potential strategies to modify or enhance those systems to improve indoor air quality and reduce the spread of infection. Many of the following recommendations are in conformance with the ASHRAE EPIDEMIC TASK FORCE document published May 5, 2020 for Schools & Universities.

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SPACE TYPE	SYSTEM(S)	UVC IN HVAC	UVC IN ROOM	ENHANCED FILTRATION	BI-POLAR IONIZATION	PRESSURIZATION & AIRFLOW	HUMIDIFICATION	COMMENTS
Classroom	AHU/RTU	Yes	Yes - Upper Room	In AHU	Yes	Neutral	Central	Can be Single Zone or Multi-Zone VAV
	Unit Ventilator	N/A	Yes - Upper Room	Portable	Portable	N/A	Local or Portable	
	VRF/HP/FCU	Yes	Yes - Upper Room	Portable	Yes	Neutral	Central, Local or Portable	
Theater	AHU/RTU	Yes	No	In AHU	Yes	Negative	Central	
Gym	AHU/RTU/H&V	Yes	No	In AHU	Yes	Negative	Central	
Kitchen	AHU/RTU/H&V	Yes	No	Unnecessary	Yes	Negative	Central	
Cafeteria	AHU/RTU/H&V	Yes	No	Yes	Yes	Positive to kitchen	Central	
Faculty/ Admin.	AHU/RTU	Yes	Yes - Upper Room	In AHU	Yes	Negative	Central	Can be Single Zone or Multi-Zone VAV
	VRF/HP/FCU	Yes	Yes - Upper Room	Portable	Yes	Negative	Central, Local or Portable	
	Unit Ventilator	N/A	Yes - Upper Room	Portable	Portable	N/A	Local or Portable	
Nurse	AHU/RTU	Yes	Yes - Upper Room	In AHU	Yes	Negative	Central, Local or Portable	Can be Single Zone or Multi-Zone VAV
	VRF/HP/FCU	Yes	Yes - Upper Room	Portable	Yes	Negative	Central or Portable	
Public, Private, Shared Restrooms/ Showers	Exhaust	N/A	Yes - Surfaces	N/A	N/A	Negative	N/A	

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Applications

There are a number of variables that affect how the strategies and technologies described above can be applied to new school system's designs and the evaluation of systems on existing schools. The following sections describe considerations that should be made when evaluating them.

Enhanced Filtration

Classroom	Theater	Gym	Cafeteria	Faculty/ Admin	Nurse

All HVAC systems have filters to catch particles and contaminants, but typical filters are not able to capture smaller particles that could be carrying the COVID-19 virus. ASHRAE's position is that "Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures." Since the COVID-19 virus is transmitted and carried by occupants and may be in the air stream, installing high efficiency filters in the mixed air streams (return & outside air) provides the best method for capturing contaminants. Each HVAC system should be analyzed to determine if the air handling units have sufficient capacity to add filtration and/or increase the MERV rating of existing filters. Physical space for enhanced filters within the units should also be evaluated.

Air handling units for K-12 schools are typically designed with two levels of filtration; a MERV-8 cartridge filter for large particles on outdoor airstreams and then a MERV-13 cartridge filter for finer particles. MERV-13 filters are effective against pollens, car emissions and bacteria, but much less effective against free (non-attached) viruses. Designing for 12 inch cartridge/box filters allows for the opportunity to provide higher efficiency filters for either continuous use or on an as needed basis. Filters with efficiencies up to MERV-16 can be effective for capturing attached viruses or small airborne aerosols containing viruses. While MERV-13 filters have a particle size capture efficiency of about 75% for particle sizes between 0.3 and 1.0 microns, a filter with a MERV-16 rating has an efficiency of up to 95% and high efficiency filters (HEPA) can capture 99.97% of these particles.

Filtration solutions should be considered for mixed air systems like variable air volume or constant air volume systems that have a high percentage of recirculated air because the return air stream is where most of any airborne viruses would exist. Designs that apply dedicated 100% outside air systems (DOAS) have become common practice for increasing energy efficiency in schools, but they do not benefit from the use of higher efficiency filters since recirculation of the ventilation air takes place at the space level. Air that is returned to the DOAS units is exhausted out of the building and is not recirculated back to the spaces. Typically, the DOAS units will have a form of energy recovery media that passes energy between the exhaust and the fresh air streams in order to precondition the incoming fresh air. If the units have this energy recovery capability, high efficiency filtration should be used on the exhaust air stream to reduce the risk of passing contaminants to the incoming air stream.

The main disadvantage to utilizing HEPA or ULPA filters in an existing HVAC system is the high pressure drops caused by these closely weaved filters. To minimize the pressure drop and the impact to an existing fan system, lower depth HEPA filters may be utilized. There are high efficiency filters with low pressure drops that can be applied, however these are typically much larger. Existing systems may be assessed to determine the need to install larger fan sheaves, replace motors, replace fan wheels, and/or replace fan assemblies to overcome higher static pressure requirements. Booster fans may also be added to accommodate the higher pressures. Designers and owners will need to consider both energy efficiency and filter efficiency when making their selections or and/or decisions.

For terminal unit systems that are typically served by the DOAS units and recirculate air within the space (fan coil units, chilled beam terminal), high efficiency filters are not applicable as the terminal units are not capable of handling the higher pressure drops.

Local in-classroom systems, such as unit ventilators, typically only include two-inch pleated filters which may be MERV-8 efficiency. These may be replaced with two-inch MERV 13 filters to provide some level of protection but these filters are only marginally effective at removing viruses.

To further enhance the effectiveness of filters, it is advisable to utilize filters with antimicrobial coatings. Filters may be treated with antimicrobial coatings to deactivate dangerous microbes on contact.

Pressurization and Airflow Strategies

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse	Restrooms

In general, all buildings should be under a slight positive air pressure. A building under negative air pressure will allow unfiltered air to enter and bring contaminants that are typically filtered by the air-handling equipment. Pressurization techniques may be employed to minimize the risk of outside contamination not carried in by people or materials. Changes in pressurization relationships may require modifications and/or rebalancing of the central makeup air equipment and fans.

For systems with demand ventilation controls, these controls should be deactivated (during this crisis period) to maximize the amount of outside air introduced into the spaces. Adequate heating capacity will be needed at the space level to apply this strategy and prevent overcooling of spaces. This strategy has a high impact on fan electrical energy consumption and heating fuel consumption.

Application of more frequent cleaning procedures within building areas will release chemicals into the air. In buildings with a central HVAC system, the implementation of flush-out cycles will dilute the air of these chemicals. Flush out cycles may be operated for short durations, multiple times per day, to match the frequency of cleaning. During unoccupied periods, the amount of outside air may be increased beyond minimum outside air setpoints. If interior conditions (temperature and relative humidity) are relaxed during this flush-out period, it will be possible to further increase the amount of outside air during peak cooling and heating months when utilizing HVAC equipment that was not originally designed for these greater outside air percentages. Depending upon existing controls in place, it may be possible to enact automatic reset of outside air volume, based upon a schedule or monitoring of interior conditions during these flush out cycles, by simple reprogramming of the control sequences

Ventilation strategies that increase outside air will help provide higher dilution levels and reduce the concentration of contaminants within the space. Nevertheless, providing increased ventilation rates can be one of several strategies applied towards an overall solution. Increasing ventilation air rates by 30% qualifies for a LEED credit. This credit is not typically applied because of the increase in energy consumption needed to condition the additional outside air. In a new building design, this increase in ventilation can be implemented as a manual override via the building automation system only when needed, such as during an afterhours building flush out, or when the outside conditions are optimal.

Mixed air systems with 100% outside air economizer cycles can be designed to readily switch to an increased outside air ventilation mode if the system design capacities (heating and cooling) can handle the increased load. Also, the occupants may be able to accommodate altered space conditions (space a little warmer or cooler) for a temporary amount of time when the outside air can be increased beyond the systems original design.

Designing DOAS ventilation systems for increased outside air capacity or an increased outside air mode will have a direct effect on the size of ductwork and fan motor. Therefore, increasing outside air capacity for a DOAS system will have a more direct impact on the system design than a mixed air system with economizer.

Since DOAS system exhaust is often combined with many toilet exhaust systems, include an override mode to operate toilet exhaust systems continuously during unoccupied hours. This can be accomplished with continuous operation of the general ventilation system.

Designing for differential pressurization of spaces is not seen as a highly effective strategy for K-12 applications by ASHRAE, although a slight negative pressure in classrooms and positive pressure in the common corridors can help to isolate contamination with the classrooms and reduce spread into common areas. Common corridors can also carry airborne contaminants left over from earlier classroom transitions. Nurses or health services spaces, in addition to locker rooms, restrooms and kitchen spaces, should be negatively pressurized with respect to their adjacent spaces.

Classrooms with unit ventilators will typically have exhaust fans that serve multiple classrooms, verify these exhaust fans are working properly. Also verify existing building systems with unit ventilators are operating properly, verify outside air settings and check that outside air dampers are in working order.

UVC Strategies

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse

UVC lamps have many potential uses throughout schools. UV light within the duct system can be used to kill microorganisms in the airstream. However, placement is important since the coronavirus must be exposed for a period that requires multiple UVC lamps within the airstream. Manufacturers recommend exposure of 10 seconds within proximity of the UVC bulb with some suggesting spacing lamps every 12 inches. Properly applied, UV lamps may reduce active coronavirus up to 90% as indicated in emerging research.

Areas where UVC lighting could effectively deactivate the virus within the ductwork/HVAC system are areas that may trap particulate containing the coronavirus. These include sound attenuators, filters, energy recovery wheels, coils, and fans. However, if effectively applied, it may only be necessary and cost effective to treat one specific location within an air handling unit.

Widespread use of UVC Light in common settings is limited because conventional UVC light sources are both carcinogenic and cataractogenic. However, it has been determined that far-UVC light (207–222 nm wavelength) efficiently inactivates bacteria without harm to exposed human skin, when the proper filters are applied. This is because far-UVC light cannot penetrate even the outer (non-living) layers of human skin, due to its strong absorbance in biological materials. However, because bacteria and viruses are of micrometer dimensions, far-UVC can penetrate and inactivate them. Far-UVC efficiently inactivates airborne aerosolized viruses, with a very low dose of light inactivating >95% of aerosolized H1N1 influenza virus.

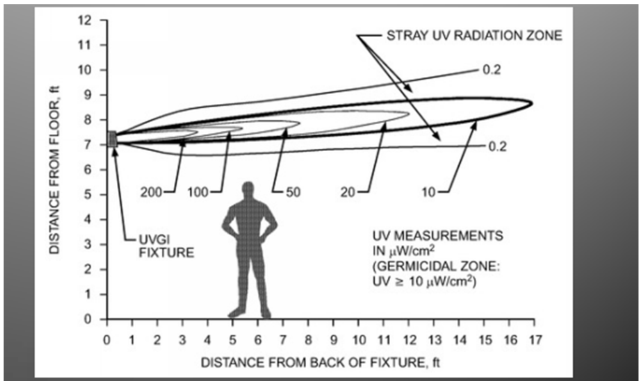
Special consideration is needed for spaces serve by a dedicated outdoor air unit (DOA) with energy recovery. All of these units have, at least, one energy recovery wheel, and some have a second energy recovery wheel used for reheat. For this application UVC lights should be placed in the unit to disinfect the surface at the heat recovery wheel(s) to avoid cross contamination.

The viability of far-UVC light for direct surface disinfection within occupied spaces is still being researched. The current restrictions and concerns of far-UVC light on human eyes is under review by the governing bodies. It is possible far-UVC light will be deemed as safe for occasional direct exposure, as long as no direct light is received by the eyes.

Upper-air (air that returns up at the ceiling level) UVC strategies may be effective in classrooms with good air recirculation. The disinfection zone needs to be properly planned and tested to ensure that it is above the acceptable occupied zone exposure since UVC light can be very harmful to an occupant's skin and eyes. Shown in the table here are the National Institute for Occupational Safety & Health UVC dosage limitations. As shown, the 8 hour limit can be considered the standard limit for continuous disinfection of an occupied space. A recent study which monitored workers and patients in a healthcare space with a continuous upper-air germicidal ultra-violet (GUV or UVC) installation demonstrated that no one exceeded 1/3 of the 8-hour limit.

NIOSH Limits for 253.7 nm UVC

- 1 s: 600 $\mu W/cm^2$
- 1 min: 100 $\mu W/cm^2$
- 1 hour: 1.7 $\mu W/cm^2$
- 8 hours: 0.2 $\mu W/cm^2$ (standard for upper-air)



2019 *ASHRAE Handbook—HVAC Applications*, Ch. 62, Fig. 6

UVC light and its effect on individuals that come in contact with it still requires a lot of research for safe implementation and requires further development.

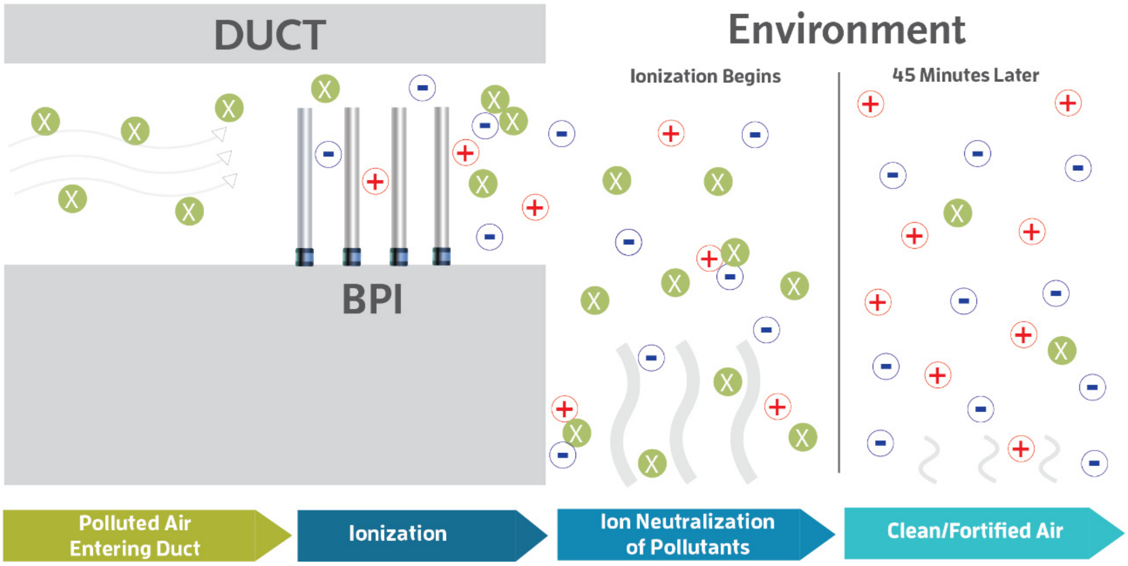
Bi-Polar Ionization

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse

Bi-polar ionization could have wide use in schools. This technology may be deployed in theaters, classrooms, and communal spaces with central HVAC systems with adequate space in the AHU's to accommodate this technology. This technology works by releasing positive and negative ions into the airstream as noted on the diagram below. Air flows along the ionization tube and oxygen from the air is charged to form ions. The ions are attracted to airborne particles like dust, smoke, VOCs, allergens and other air pollutants. Charged particles are drawn together, forming clusters, which become heavy enough to drop out of the air. These ions work to deactivate single-celled, carbon-based organisms such as fungi, viruses and bacteria whether they're in the air or resting on surfaces. Bi-Polar Ionization can be installed in ductwork or deployed in spaces like common areas. To maximize effectiveness, the air circulation and BPI systems should operate continuously.

This system can be applied in both mixed air systems and DOAS systems, although it may be more effective for mixed air systems due to the higher amount of air supplied to the space.

Small amounts of ozone can be created by these systems which should be monitored, and additional exhaust systems should be considered within the spaces.



These systems tend to be expensive and in systems with mostly recirculated air within each space (fan coils, chilled beams, etc) it may be cost prohibitive. In room ionization systems may be utilized on a temporary basis, if required.

Humidification

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse

Humidification should also be considered to help minimize the spread of contagions. Humidity levels above 40% inactivates almost 80% of viruses within 15 minutes according to early published research. More recent research has shown that humidity may not directly affect the virus itself, but it does help humans fight-off the virus. The moisture generated by the humidity level allows our cilia and mucus membranes to capture and repel the virus. Maintaining a relative humidity of 40-60% RH helps to contain the virus and promotes efficient immune system response. Maintenance issues should be examined for all humidification systems because of the increased risk of indoor air quality issues with these systems. Humidification introduced by steam injection is a logical choice, but other methods, such as ultrasonic or spray injection, may be explored if sanitization of the system is maintained. Systems that rely on maintaining standing water are not recommended.

Since the majority of school HVAC systems may not utilize humidification, these systems would need to be retrofitted, which will require a clean water source, a unit coupled with energy to heat and inject moisture, and a distribution method – either by injection into a duct system or the use of area humidifiers that inject moisture directly into the occupied spaces.

Implementation and maintenance of increased humidity levels in existing systems can be costly and require additional energy and space for water vapor producing equipment. Tight envelope construction is also required and in colder climates additional monitoring of space humidity is needed to ensure surface condensation does not occur.

Portable Air Purification

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse	Restrooms

Another option to increase air changes within a space while treating the airflow is the use of multiple local air purifiers. These provide the ability to increase air changes when the existing HVAC systems are unable to increase airflow. There are a wide variety of portable units that use UV lights in an enclosure with a fan to move room air across the light. As an alternate, bi-polar ionization can be deployed in the same portable manner for air purification. Other portable units use a media of activated carbon and potassium permanganate as a sorbent to absorb the contaminants in combination with a HEPA filter. These units employ a fan to move room air thru the multi-stage filter. Portable units are easier to deploy and may be moved as needed to accommodate changes within the environment, including common spaces.

Sanitizing Ductwork

Classroom	Theater	Gym	Kitchen	Cafeteria	Faculty/ Admin	Nurse

The process of sanitizing HVAC equipment and ductwork warrants careful consideration. Ductwork systems may be sanitized with aerosol sprays of disinfectant solutions in unoccupied spaces. During treatment by aerosol disinfectant solution, outside air should be closed to allow 100% recirculation of the disinfectant to minimize dilution and increase its effectiveness. Because the viability of the virus is minimized within ductwork systems due to use of filters or other strategies listed within this paper, ongoing or continuous sanitizing of ductwork is not necessary. Aerosol disinfection can only be used in unoccupied spaces.

PLUMBING SOLUTIONS

Since coronavirus may be transmitted through respiration, touch and fecal-oral transmission, restrooms, locker rooms, and cafeterias will require special attention. Though surfaces may be cleaned as previously noted and HVAC systems enhanced, additional measures are recommended to maintain functional restrooms for students and faculty. The following strategies may be applied:

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- Spray disinfectant applied to toilet bowls during and after each flush.
- Hands free faucets:
    - In existing school buildings, investigation of piping configuration should be performed to ensure adequate hot water can be provided with the use of hands free fixtures.
- Hands free toilet fixtures:
    - In existing school buildings, investigation should be performed to ensure new hands free flush valves can work properly with existing urinals and toilet bowls.
- Add lids onto toilets to be able to close lids when flushing.
- Adopt procedures to minimize the dispersion of the virus in the restroom, such as limiting use of stalls with adjacent occupancy and closing lids when flushing toilets.

As noted in the UVC section for HVAC systems, UVC light and its effect on individuals that come in contact with it still requires a lot of research for safe implementation and requires further development. As this technology becomes widely accepted for safe use, the following are some future applications:

- Far-UVC or UVC lamps under lids of toilets.
- Far-UVC or UVC lamp to disinfect stall after each usage.
- Far-UVC or UVC lamps in lids of waste bins.

Recent research findings now indicate that COVID-19 is not being found in water supplies.

TECHNOLOGY SOLUTIONS

When students return to the classroom, maintaining access to critical digital teaching tools and resources will require reducing the number of common touch points and creating a cleaning program for shared technology devices. In critical environments or those with close-quarters working conditions, detecting staff who may be ill and reducing contact with common technology surfaces will help reduce the spread of the virus.

Consider the following upgrades or modifications to existing technologies:

- **Reduced Touch Interfaces** – Shared technology programs (iPad or classroom PC group instruction) create common touch points which should be avoided unless a comprehensive device cleaning program has been implemented. When a 1:1 distribution of technology per student is not practical, consider suspending shared technology programs or breaking classrooms into smaller groups and staggering usage to allow for cleaning between sessions.
- **The Split Classroom –** Many institutions are considering options to split classes with on and off days for in person and remote attendance. While this may help to re-engage students and offer some of the traditional learning environment back that has been lost during social distancing, it is critical to provide high quality capture capabilities so when students are remote they don't suffer from a loss of intelligibility or classroom experience. Anticipate a need to retrain

instructors on how to effectively teach to both in-room and remote participants simultaneously and train them on how to use the AV capture systems provided.

- **Guest and Visitor Screening** – Consider deploying small formal thermal screening appliances to help with access control. These systems speed the temperature checks and reduce staff contact during screening. These cameras are best deployed as standalone monitoring stations and some manufacturer options allow for group screening under specific conditions. Environmental factors can greatly affect the accuracy of these devices. Guidelines for distance, number of persons being scanned, and other calibration factors must be followed.

- **Access Control –** Explore mobile credentialing options with your existing security platform for reduced touch access control. Provide a simple non-contact stylus to users for opening doors and pushing elevator buttons while evaluating options for automatic door openers.
- **Learning Continuity –** Future lesson plan development should focus on the ability to deliver in person and remotely. This will ease future transitions to remote teaching which may be required due to increased infection rates or changes in stay-at-home orders.
- **Training & Adoption -** With the increased adoption of collaboration technology that most educators are experiencing, continuing to use those technologies and improving the effectiveness of the platforms will require ongoing training and process improvement. Expect adoption to slip when reentering the classroom and adjust feature sets and educational materials as staff come to understand the limitations of social distancing within the classroom.

This quick shift to remote learning has shown us what systems are truly critical and necessary for education. Take stock of systems disabled or underperforming during the stay-at-home period and focus on addressing their connection and feature issues or begin to sunset their use. Likewise, increase the capabilities and deployment level of platforms that users heavily adopted while working and teaching remotely. Lastly, and most importantly, evaluate and examine the long-term benefits of technology platforms which remain tied to physical teaching spaces.

SCHOOL ENVIRONMENT SOLUTIONS

OTHER STRATEGIES

The primary source of the coronavirus entering the school is people. As a result, the most effective method to help reduce the spread of the virus in the school is to control access to the facilities. The number and types of barrier control necessary will be influenced by the type of building. Some barrier control solutions require careful coordination and adherence to life safety codes. For example, if you create a single access point for a building, secondary access points will need to be converted to exit only, self-locking type to maintain egress. An architect or other life safety professional should be consulted to ensure adherence to the applicable codes.

Based on current CDC recommendations to maintain 6 feet separation, queue lines for entry points may need to be used with appropriate spacing to relieve congestion at entrances. Other school specific strategies for distancing include limit the number of people in each classroom or learning space, maintain static groups of staff and students, stagger the use of hallways and communal spaces to reduce interaction between groups and allow for regular cleaning, and reconfigure classrooms and learning spaces to allow more distance between desks or seats (6 feet if feasible).

Elevators are also a challenge for spacing and reducing touchpoints. At least one manufacturer of elevators is offering enhanced ventilation, far-UVC lights, face recognition, and voice-controlled floor request to enhance the air quality in the elevator and eliminate direct contact with the elevator surfaces.

Because the virus can survive on packages and materials**,** these should be wiped down with sanitization solution. This procedure will require space and time to process receipt of materials. Preliminary steps such as fogging shipments in small contained spaces with disinfectant may help, but recipients will need to take responsibility and steps to disinfect the contents of all packages.

Conclusion

The school environments face many challenges from the COVID-19 pandemic. Implementation of the strategies discussed above to reduce exposure and spread of the virus requires consideration of the existing systems, spaces and impacts to occupants. These strategies are most effective when combined with guidelines from government and health officials for social distancing and PPE requirements. Each day we learn more about the COVID-19 virus, how it behaves, and the best recommendations and strategies for dealing with it. We will continue to monitor and evaluate this information to present our latest insights and approaches on this matter. Our goal is to help you prepare your buildings for the safe and productive return of students and faculty.