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Ergonomic classroom design in the COVID-19 Pandemic: a study on the cross-arrangement of classroom seats

*COVID-19 Pandemisinde ergonomik sınıf tasarımı: sıraların çapraz olarak düzenlenmesi üzerine bir araştırma**

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Abstract

COVID-19, caused by the coronavirus (SARS-CoV-2), emerged in China in December 2019 and quickly spread all over the world; deeply affected people's health and life. In early 2020, in an effort to reduce the risk of COVID-19 and prevent the spread, schools around the world essentially suspended in-person education and then began distance education. However, distance education is not a method that is particularly applicable in the field of applied education. In addition, it is thought that distance education will negatively affect the careers of graduates and the country's economy in the future. Therefore, redesign of educational institutions is inevitable in order to be ready for face-to-face education under pandemic conditions. In this paper, cross-row classrooms are designed to reduce transmission in the context of the COVID-19 pandemic: In this classroom design, student rows are cross-aligned with pandemic-compatible occupational health and safety measures. The dimensions of the designed university classroom are 14.73 m x 11.31 m x 3 m and its capacity is 29 people (28 students + 1 teacher). The cross-arranged classroom design saves 36% of space compared to straight-line classrooms. The design of pandemic-compliant classrooms should also be considered from an economic point of view (i.e cost of lightinig, ventilation and construction), as the pandemic-compliant classrooms to be designed are larger than regular classrooms. Implementing face-to-face education in health and safety approved educational environments will have positive contributions to personal development and the economy in the future. Even if the pandemic will become endemic, universities should always offer online educational opportunities.

Özet

Koronavirüsün (SARS-CoV-2) yol açtığı COVID-19, Aralık 2019'da Çin'de ortaya çıktı ve hızla tüm dünyaya yayıldı; insanların sağlığını ve yaşamını derinden etkiledi. 2020 yılının başlarında COVID-19'un bulaşma riskini azaltmak ve ondan korunmak için dünya çapında okullarda büyük oranda yüz yüze eğitime ara verilerek uzaktan eğitim uygulanmaya başlandı. Ancak, uzaktan eğitim, özellikle uygulamalı eğitim alanları için uygun bir yöntem değildir. Ayrıca, uzaktan eğitimin gelecek süreçte mezunların kariyerlerini ve ülke ekonomilerini olumsuz etkileyeceği düşünülmektedir. Bu nedenle, eğitim kurumlarının pandemi koşullarında yüz yüze eğitime hazır olması için yeniden tasarımı kaçınılmazdır. Bu metinde, COVID-19 pandemisi koşullarında bulaşıyı azaltacak nitelikte çapraz sıralı bir derslik tasarlanmıştır: öğrenci sıralarının çapraz sıralandığı ve pandemi uyumlu iş sağlığı ve güvenliği önlemlerinin alındığı bir derslik tasarımı. Tasarlanan Üniversite dersliğinin boyutları 14.73 m x 11.31 m x 3 m, kapasitesi 29 kişiliktir (28 öğrenci + 1 eğitmen). Çapraz sıralı derslik tasarımı ile düz sıralı dersliğe göre %38 alan tasarrufu sağlanabilmektedir. Tasarlanacak pandemi uyumlu sınıflar normal sınıflardan daha büyük olduğu için, pandemi uyumlu sınıfların tasarımı ekonomik açıdan da değerlendirilmelidir (örneğin aydınlatma, havalandırma ve inşaat maliyetleri). Sağlık ve güvenliği onaylanmış eğitim ortamlarında uygulanacak yüz yüze eğitimin gelecekte kişisel gelişime ve ekonomiye olumlu katkıları olacaktır. Pandemi endemiye dönüşecek de olsa, üniversitelerde çevrim içi eğitim olanakları her zaman hazır bulundurulmalıdır.

** 26. Ulusal Ergonomi Kongresinde sözlü bildiri olarak sunulmuştur.*

INTRODUCTION

Many pandemics that can be considered significant in human history, as well as crises caused by epidemics, have been recorded. Pandemics have a considerable negative impact on the health of world, education, economy, industry, working life, social life and national security (Kalaycı Yüksek and Gümüş 2020). While the COVID-19 pandemic has negatively impacted many areas, its impact on education has created irreversible problems.

COVID-19 is a respiratory disease caused by SARS-CoV-2, called “Corona Virus Disease 2019” (Viramgami et al. 2020). Symbols in the COVID-19 abbreviation name; CO means corona (corona), VI virus (virus), D disease (disease), and 19 is used for 2019. CoV is a ribonucleic acid (RNA) type virus (Wu et al. 2020, Pamuk et al. 2020). It is named “corona” because of the crown appearance on its envelope (Perlman and Netland 2009, Rehman et al. 2021). There are four types of CoV variants whose effects are thought to differ: alpha, beta, delta, and gamma (Perlman and Netland 2009, Yin and Wunderink 2018, Hu et al. 2021).

The coronavirus pandemic, which emerged in China in December 2019, continues to affect the education system worldwide. COVID-19 (Novel Coronavirus Disease 2019) is known as a highly pathogenic and infectious respiratory disease caused by the SARS-CoV-2 virus. This disease was named COVID-19 by the World Health Organization (WHO) on February 11, 2020 and was declared a pandemic on March 11, 2020 (Allam 2020, Demir et al. 2021). Due to the impact of the COVID-19 pandemic, on March 16, 2020, schools in Türkiye and around the world were closed, and distance education began. The closure of educational institutions brought with it various difficulties for students, teachers and parents. For this reason, a distance education system based on digitalization has started to be implemented as a solution for the continuation of the education system (Toader et al. 2021). However, insufficient network infrastructures, computers and internet access have made distance learning difficult, especially in underdeveloped and developing countries. On the other hand, there are serious difficulties in the transfer of distance education applied science, and the phenomenon of lacking information is emerging. For these reasons, educational institutions should develop strategies to restore lost learning and bring students back to school when schools reopen. The coronavirus has also affected the face-to-face education system of all countries. Therefore, classroom design for face-to-face education should be developed and new regulations should be made to reduce the effects of the coronavirus.

Gross domestic product (GDP) will decline for the remainder of the century, as learning loss will lead to skills loss. If educational institutions are slower to return to previous performance levels, growth losses will be proportionately higher. In fact, slower growth due to skill loss in today's students will only be visible in the long run. In the context of the pandemic, some countries felt that school days and class times should be rescheduled to increase student achievement, promote equality in educational opportunities, and support families' work and family life. PISA data were used in the planning of lesson durations (Radinger and Boeskens 2021). Research findings support the hypothesis that additional teaching time will be particularly beneficial for socio-economically disadvantaged students and therefore may promote equity in learning outcomes (Patall et al. 2020). Extending the school day or school year can increase students' employment prospects, productivity and future earnings, while reducing spending on later social programs and remedial education (Brown 2005).

It is thought that learning by distance education causes significant deficiencies. Its costs and benefits are poorly known. The health and mortality risk of the pandemic incurs greater psychological costs, as does the cost of social isolation (Brooks et al. 2020, Golberstein et al. 2020). Survey evidence shows that students study less during quarantine, and some studies report differences based on home background (Andrew et al. 2020).

The World Health Organization (WHO; WHO) has foreseen the following protective measures during the COVID-19 pandemic: (1) physical distance (social isolation), (2) personal hygiene, and (3) mask applications. Governments, educational institutions and their human resources are meet enormous challenges when trying to combat the COVID-19 epidemic and take measures to protect safety and health indoors. During the pandemic process, first of all, students should be provided with physical, emotional and psychological security. Therefore, during the COVID-19 process, the hierarchy of occupational health and safety control measures should be re-evaluated and spaces suitable for the epidemic should be designed in order to prevent the spread of the coronavirus in educational institutions.

SARS CoV-2; It is transmitted from (1) animal to human and (2) human to human (Yin and Wunderink 2018). The virus enters the lungs through the nose, larynx and respiratory tract; it affects the lungs, heart, kidney and gastrointestinal systems (Türken and Köse 2020, Saydam 2020). Its clinical development can be asymptomatic or at the level of severe respiratory failure requiring oxygen support, and even fatal (Phan 2020, Çelik and Köse 2020). The virus can be detected 1-3 days before symptoms. The viral load is highest at symptom onset and decreases over time. The duration of COVID-19 positivity is generally 1-2 weeks in asymptomatic individuals, 3 weeks or more in

mild to moderate disease, and this period can be much longer in severe patients (Pan et al. 2020).

Transmission of the virus between humans occurs by two mechanisms:

1) Airborne transmission: It is transmitted via direct by human- spread virus-laden droplets (Figure 1). The majority of transmission occurs this way (Azimi and Stephens 2013).

2) Indirect contact transmission: It spreads when human-induced virus-laden droplets settle on various surfaces and objects. This type of infection rate is lower.

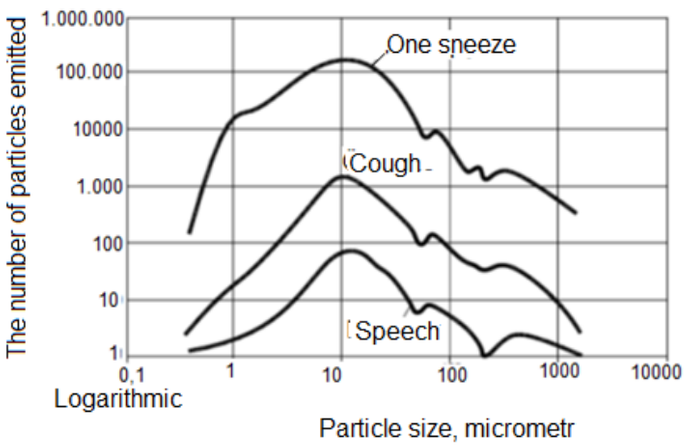

Figure 1. Amount and dimensional distribution of particles emitted to the environment by an infected person (Köksal 2001)

COVID-19 data for the World and Turkey as of 19 December 2021 and 14 August 2022 are given in Table 1. As of 19 December 2021; 8.7 billion doses of vaccine have been administered in the world and a total of 124 million doses of vaccine have been administered in Turkey (URL-1 2021, URL-2, 2021, OSHA 2020). On the other hand, as of August 14, 2022, the number of cases in Turkey was 16.67 million, the number of deaths was 100,400, the number of cases in the world was 599 million and the number of deaths was 6.5 million.

The risk of exposure to SARS-CoV-2 depends on the workplace environment, work activities, the health status of the employee, the use of personal protective equipment suitable for the conditions, the skills and habits of following the health authority instructions, the need for close contact (2 meters in 24 hours, a total of 15 minutes. or more), depending on social conditions and social living conditions.

Symptoms that mark the complete separation of COVID-19 from other viral respiratory diseases have not yet been identified. Common symptoms; is the fever, dry cough, difficulty speaking, difficulty moving and breathing, chest pain, new confusion, inability to wake up or stay awake, skin discoloration; Less common symptoms are; is the fatigue, headache, sore throat, muscle-joint-body pain, diarrhea, conjunctivitis, loss of smell and taste, nausea and vomiting, nasal congestion and discharge, burnout (Çelik and Köse 2020, OSHA 2020).

Two tests are used to diagnose COVID-19: a) Diagnostic test (NAAT and PCR), b) Antibody test.

The pandemic has revealed the level of defense of the world against crises, the level of stability of economies and the level of inter-country dependence being affected by the global structure.

COVID-19 has various adverse effects in the following areas (Haleem and Javaid 2020); health, economy, social, education and other fields. COVID-19 causes costs such as loss of care and workforce, as well as deterioration in personal health quality. The epidemic process has led to a decrease in the global trade volume and the deterioration of financial systems (CRS 2021; Dokuzoğlu ve Tüm 2022).

Although technological developments contribute to the implementation of distance education; The quality of education, especially applied education, is declining, and it is thought that young people who grow up under these conditions will not be able to achieve the desired performance in business life. The COVID-19 pandemic and the resulting economic downturn have adversely affected the mental health of many people (Schäfer et al. 2020). On the other hand, as of 2020, less energy was used and CO2 emissions decreased by 5.8% (Khan et al. 2021).

Pandemic risks have left governments' educational institutions in an extremely difficult dilemma:

a) Closing educational institutions to reduce contacts and save lives.

b) Keeping workplaces and educational institutions open to allow workers to work and to sustain the economy.

The effective, powerful and efficient solution of possible problems in the future will depend on the foresight,

readiness and preparedness of the governments. Education systems will be at the center of this planning in meeting social demands. This is a closed cycle that requires a strong level of education to strengthen the economy and a strong economy to strengthen education.

Table 1. COVID-19 case data in the world and in Turkey

	World		Türkiye	
Status	19 December 2021	14 August 2022	19 December 2021	14 August 2022
Number of cases	274,668,232	599,224,633	9,154,209	16,671,848
Number of recoveries	246,498,485	573.206.913	8,762,742	15,487,468
Number of deaths	5,368,999	6.467.127	80,224	100,400
Number of active cases	22,802,739	19.550.593	311,223	1.083,980
Total number of vaccines	8,700,000,000	12,510,000,000	124,058,691	151,133,348

It is not known when the COVID-19 disease outbreak will end. For these reasons, all countries have to make efforts to recover the future losses in education (Donnelly et al. 2021).

The epidemic appears to continue, interrelatedly, with the following adverse effects: (a) reduction in human capital accumulation, (b) reduction in development prospects, and (c) reduction in welfare.

If the future effects of the pandemic cannot be contained, both students and the whole society will suffer (Balcı 2020). In fact, the weakening of market conditions and the decline in career prospects due to the quality of education will result in lower-paying jobs being accepted, which will have lasting negative effects on careers (Oreopulos et al. 2012).

Negative situations that can be experienced in the distance education process may appear as low morale and motivation in students, distrust of the education system and themselves (Çakın and Külekçi Akyavuz 2020, Kutluay Tutar et al. 2021). In the long run, the working life of graduates is adversely affected. In such a case, it is inevitable to design pandemic-compatible classrooms and to take pandemic-oriented occupational safety measures in order to prevent contamination.

In the 2.5 years since the first infection, there has been significant research and publications on COVID-19. In this study, it is aimed to design the appropriate educational environment for the conduct of face-to-face education.

MATERIAL AND METHOD

Within the scope of the research, evidence-based documents such as articles, communiqués and institutional catalogs related to COVID-19: The characteristics, transmission routes and effects of SARS-CoV-2, its negative effects were examined worldwide, and then classroom designs that would contribute to reducing the transmission of COVID-19 were evaluated. Cross-row classrooms were designed and compared with straight and regular-row classrooms.

Classroom Dimensions: For classroom dimensions, Önder et al. (2013) was used. The height will be at least 3 m, the corridors between straight rows will be 0.80 m, the minimum area per student will be 2 m^2 under normal conditions and 4 m^2 under pandemic conditions (MEB 2021).

Student Desk: Relevant sources were used for seat, backrest and student desk dimensions (TSE 2016, Kahya et al. 2018, Tunay et al. 2005, Akın et al. 2014). The horizontal projection and dimensions of the row (table and seat) where each student will sit are shown in Figure 2.

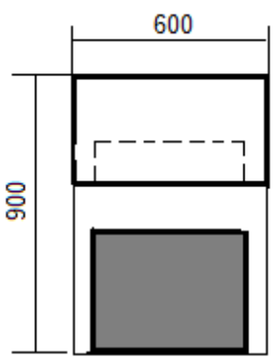

Figure 2. Student desk and seat; top view / projection

Lighting: For natural lighting, the window area should be at least 20% of the floor area. Correct lighting practices increase work efficiency, increase production quantity and quality by improving visual performance as well as

energy saving. The area index used to determine the lighting efficiency factor is calculated with the help of Equation 1 (Üçüncü et al. 2014).

$$k = \frac{a*b}{H\ (a+b)} \quad (1)$$

In this equation; k: space index, a: short side length of the space (m), b: long side length of the space (m), H: distance between luminaire and working surface (m). The distance between the luminaire and the working surface, h_1: the distance between the working surface and the floor (0.72 m), h_2 the luminaire-ceiling distance (0.18 m) was calculated from the equation 2 (Üçüncü et al. 2014).

$$h = H - (h_1 + h_2) \quad (2)$$

The number of luminaires is the ratio of the required total luminous flux to the luminous flux of the lamp and is calculated with the help of equation 3

$$n = \frac{\emptyset_T}{\emptyset\eta} \quad (3)$$

Total required luminous flux (lumen):

$$\emptyset_T = \frac{d\ E\ A}{\eta} \quad (4)$$

The number of luminaires is found with the help of the following equation 5.

$$n = \frac{d\ E\ A}{\emptyset\ \eta} \quad (5)$$

Here; d: the contamination/maintenance factor of the facility (d = 1.25), A: the area of the space, A = axb (m^2), E: the illumination intensity of the space, 500 lux was chosen as the catalog value (TSE 2013a, Bostancı Başkan and Şerefhanoğlu Sözen 2006). η: is the lighting efficiency of the space. Lighting efficiency varies according to the materials of the ceiling, wall and floor, that is, the reflection coefficients and the space index. The reflectance factor of the ceiling is ρ_t, the reflection factor of the walls is ρ_d, and the reflection factor of the floor is ρ_z (MEB 2007).

Ventilation: The coronavirus is contagious between people who are in close proximity by inhalation. Indoors, there is very little airflow to disperse and dilute viral particles; therefore, the risk of transmitting the coronavirus to another person nearby is higher than outside. Improvements to indoor air alone will not stop the spread of the coronavirus; therefore, ventilation should be considered along with other measures to help reduce the spread of disease. Ventilation should be combined with actions such as using a mask, staying at least 2 m away from others, maintaining frequent hand hygiene, cleaning and disinfecting frequently touched surfaces.

Ventilation is a component of protecting healthy environments from viral infection and is the most important coronavirus prevention strategy for schools. With good ventilation, the amount of virus particles in the air can be reduced; therefore, ventilation, along with other preventive actions, is an effective technique to reduce the likelihood of disease spread. Space volume, occupancy rate and mode of operation are the most effective factors in ventilation. The larger the area allocated per person, the lower the risk. As the number of people per unit area increases, the risk of an infected person being there will increase, so the aerosol density and exposure to aerosol increase. The risk increases if an area is poorly ventilated and occupied by more than one person. High physical exertion or loud talking will require deeper breathing, increasing the risk of aerosol production and transmission. Such activities increase the risk of contamination, even where there is adequate ventilation.

In natural ventilation, natural ventilation can be improved by fully or partially opening windows, vents and doors.

The risk of particle contamination can be reduced in two ways; (a) not allowing infected workers or people with COVID-19 symptoms to come into the workplace; and (b) providing adequate ventilation with fresh air (TTB 2020). Ventilation will reduce the risk of particles, but the positive effect on the following factors is very low: (a) droplet transmission (from people with close human contact) and (b) contact transmission (human-touch surfaces). Ventilation is applied in proportion to the occupancy of the space. A sufficient amount of fresh air can be provided in any work area in two ways: (a) Natural ventilation - fresh air enters through open windows, doors or vents. (b) Mechanical ventilation - fans and ducts bring fresh air from outside.

Equation 6 was used in the airflow calculation.

$$Q = n\ V \quad (6)$$

Here, n is the number of air renewals and V is the classroom volume. The recommended per capita air flow rate for schools that can be accepted in the light physical

work category is 50 m^3/h, and the number of air renewals for classrooms is 5-7 (DIN 2008, URL-3 2021).

Other Equipments: The width of the classroom doors should be at least 90 cm, the doors should be between the front row and the blackboard and open towards the corridor. The door height is determined according to the size person. Standard dimensions for the blackboard are 120x280 cm. The projection and dimensions of the teacher seating arrangement are shown in Figure 3. TS EN 527 series of standards are used for desks and desks in offices (TSE EN 527-1 2013b, TSE EN 527-2 2017, TSE EN ISO 527-3 2019).

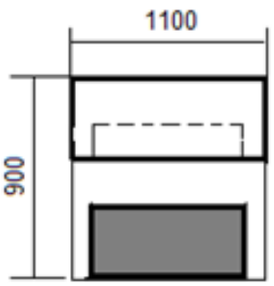

Figure 3. Teacher's desk and chair; top view / projection (mm)

In the classroom design, it should be ensured that students both receive the education they need and be safe. If the pandemic continues like this, such an application may also provide serious opportunities for the construction industry in the long run. Additional criteria to normal conditions should be taken into account in the design of pandemic-compatible classrooms. Underlying these standards is a pandemic prevention approach; masking, distancing and cleaning habits will be created.

1) Keeping teachers, students, education support staff, and guests safe should be a priority in the design of learning spaces.

2) A classroom design that supports interaction between students should be created while maintaining the design in accordance with the distance protocols. Since the practice of distance will lead to the enlargement of the classrooms, it will be necessary to reduce the number of students in the classroom. Layouts that safely separate students but facing each other can be helpful.

3) While providing students with appropriate field of view and distance, the teacher's workspaces can be reduced, even if it annoys the teacher. It is necessary to have creativity in which the remaining space from the teacher's field can be used effectively.

4) Although the distance between the rows is designed in accordance with the pandemic conditions; Sometimes coughing, sneezing or speaking loudly in the classroom can increase transmission (Figure 1). Sneeze guards should be used where face-to-face interaction is required. Students may need to be close to get one-on-one feedback from teachers and collaborate with one another. Intelligent use of sneeze guards can allow for a sense of normalcy while ensuring safety.

5) Unnecessary elements that cause students to come together should be removed. Protective measures should be taken by preventing students from standing at close distances from each other in joint studies. Classroom design should easily meet the individual needs of students.

6) While being separate from the classroom design, common areas (canteen, reading room, halls, stairs, washbasin, WC, etc.) should be designed in harmony with the pandemic. However, social distancing and hand washing facilities can be improved in schools.

RESULTS AND DISCUSSION

The COVID-19 experience has revealed two situations; (1) It is not known how long the pandemic will last, and (2) It is impossible for schools to remain closed for an unknown period. There is not enough information about COVID-19 and the possible consequences of the pandemic yet. This uncertainty situation reduces the reliability of the predictions (Tanhan 2020). Therefore, despite the economic difficulties, it is inevitable to design pandemic-compatible environments and most importantly, classrooms in the schools to be opened.

In the design of the classroom, only the elements related to the functions for lesson purposes will be taken into account, and the general elements of the building construction will not be taken into account. However, it is assumed that other elements will be designed and manufactured as specified in the project. The classroom will be designed according to the normal conditions (hybrid or flexible) as well as the pandemic conditions. Providing social distance and cost are important constraints in classroom design. The effect of the cross-row classroom design on the cost and the effectiveness of social distance were evaluated.

In this study, it is aimed to design an ergonomic classroom in accordance with the distance rule, which reduces the risk of the Covid-19 pandemic. The capacity of the classroom to be designed is 28 students. Other usage areas of the classroom (blackboard, window, teacher's chair, etc.) will be designed in accordance with ergonomic principles, and the dimensions of the classrooms and the area per instructor and student in the classroom have been calculated in accordance with the pandemic conditions. Except for the classroom dimensions, the lighting in the classroom will be adjusted so that education can be done day and night. T.R. The field design was planned by adhering to the COVID-19 epidemic management study guide published by the Ministry of Health in 2020:

a) Classrooms should be arranged in such a way that the distance between teacher and student is 1 m and masks should be used.

b) Face-to-face sitting should not be allowed in classrooms, and arrangements should be made for diagonal sitting.

c) Those who are likely to have contact closer than 1 m should use a face shield as well as a medical mask. 70% alcohol can be used for cleaning the face shields.

d) An area of 4 m^2 per person should be allocated in the areas where the educational institutions are actively present.

Space Requirement: With the nearest 2 m distance between people in the classroom environment, 4 m^2 of space will be needed for each student in a straight-line arrangement. For the same number of students, studies were carried out on a different classroom design by using less space suitable for pandemic conditions, and it was planned to design the classroom in a diagonal order. Figure 4 shows the cross-layout cell. The classroom will have a capacity of 28 students and 1 instructor. Rows 2 and 3 of the classroom can be arranged as rows of disabled people. According to the determined criteria, the classroom area was found to be A = a x b = 11.31 m x 14.73 m = 166.6 m^2 (Figure 5-6).

A minimum volume of 12 m^3/person x 29 people = 348 m^3 is required for 28 students + 1 instructor = 29 people. Since the area is 166.6 m^2, the minimum height of classrooms should be 348 m^3 / 166.6 m^2 = 2.1 m. In this case, the standard classroom height was taken into account and the classroom height was determined as 3 m.

If the same classroom is arranged in a straight row for COVID-19 conditions, the classroom capacity will be 20 students. In this case, the cross-row classroom will have 38% higher capacity than the straight-row classroom (Figure 7).

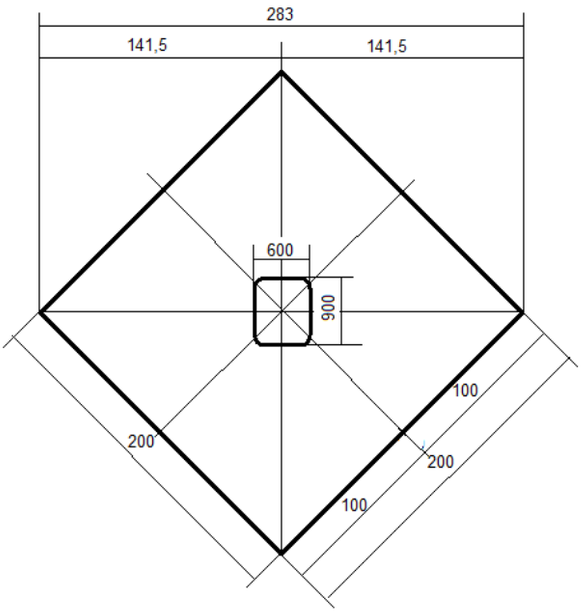

Figure 4. Diagonal placement cell (cm)

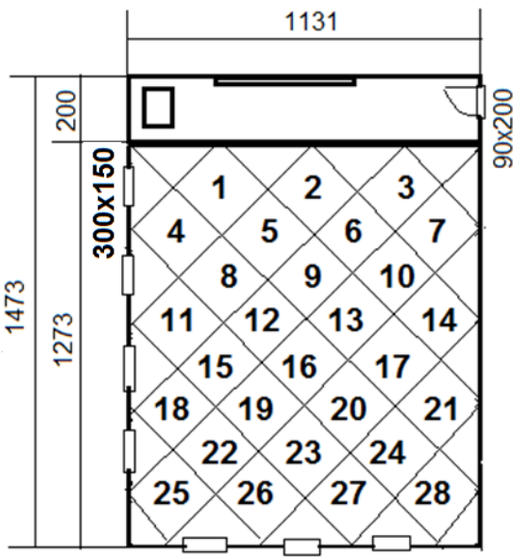

Figure 5. Cross-row classroom plan (cm)

If the classroom with the same dimensions is designed in straight rows for normal runs, it will have a capacity of 96 students. However, in this case, the problem of insufficient volume per capita should be carefully considered (Figure 8).

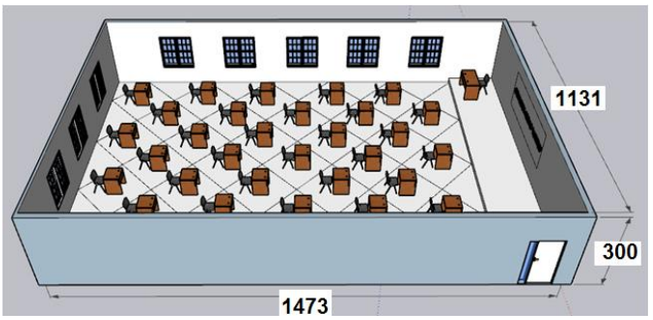

Figure 6. 3D image of diagonal row classrooms

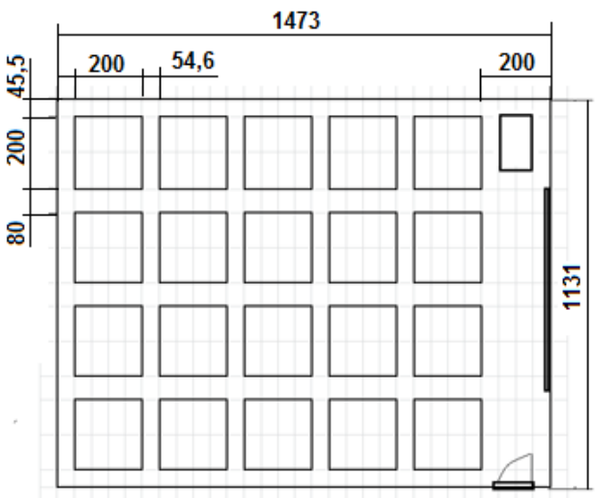

Figure 7. Flat-row classroom design for COVID-19 conditions

For COVID-19 conditions, the average area per person is 166.6/29 = 5.745 m^2 in case of cross-row classroom design, and 166.6/21 = 7.933 m^2 in case of straight-row classroom design. If the 29-person classroom is designed in diagonal rows, 166.6 m^2 will be required, and if it is designed as straight rows, a minimum of 230 m^2 will be required. Accordingly, the 29-person flat-row classroom will be 38% [(230 m^2 – 166.6 m^2)/166.6 m^2 = 0.38] larger than the cross-row classroom.

Lighting: For natural lighting, the window area should be minimum 0.2 * 166.6 = 33.3 m^2. From the equations [1] and [2], the distance between the luminaire and the working surface for artificial lighting was found to be H = 2.1 m, and the space index k = 3.0.

Soiling/maintenance factor of the facility, d = 1.25, area of the space, A = axb = 166.6 m^2, lighting intensity E = 500 lux, reflectance factor of ceiling ρ_t = 0.80, reflectance factor of walls ρ_d = 0.50, reflectance factor of floor ρ_z = 0.30, illumination yield was determined as η = 0.59. P = 36 W power, 2500 lumen/piece of luminous flux lamp was selected. From the equation (5), the number of lamps is calculated as n = 71. It has been observed that 71 TL-D 36 W/2500 lumen type fluorescent bulbs are required for the designed cross-row classroom. 24 fixtures were determined, with the lamps in the form of triple fixtures, and 28 fixtures were used as in Figure 9.

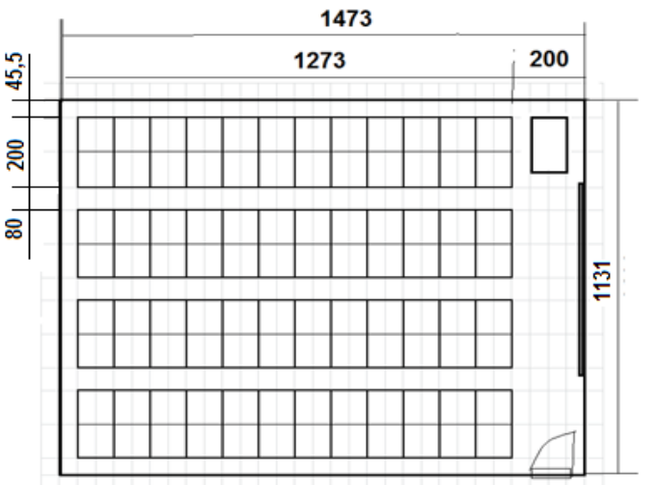

Figure 8. Straight row classroom design for normal conditions

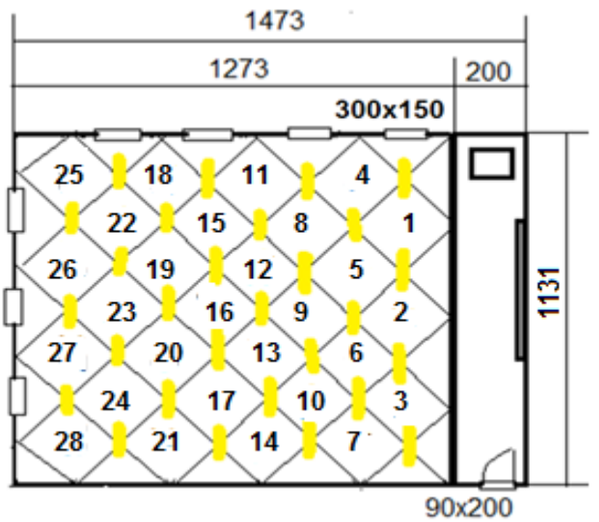

Figure 9. Cross-row classroom artificial lighting arrangement (cm)

Ventilation: With mechanical ventilation, fresh air is brought into the building from the outside environment. If the mechanical ventilation systems to be used to prevent the transmission of coronavirus are adjusted to maximize the fresh air by minimizing the circulation (indoor air circulation), they will provide adequate and effective ventilation. If the system is drawing fresh air, it can continue to operate. It is necessary to know how much fresh air it draws and whether it provides adequate ventilation. If necessary, ventilation is activated by increasing the air velocity by artificial means or, if possible, by natural ventilation (for example, opening

doors, windows or vents). The operating times of mechanical ventilation systems should be extended before and after people use their work areas.

The class has a capacity of 29 people, including 28 students and 1 lecturer. Accordingly, the minimum air flow required for the class should be: Q = 50 m^3/h.person x 29 persons = 1450 m^3/h. However, according to the recommended air renewal number for pandemic conditions (n = 5 – 7 units/hour), the air flow, was calculated as Q = 3500 m^3/h using equation [6].

In educational institutions, office and commercial buildings, filtered heating, ventilation and air conditioning (HVAC) systems are often used. In general, for the virus that causes COVID-19, it is necessary to increase ventilation and filtration. Ventilation is dependent on the complexity and diversity of building types, dimensions, construction styles, HVAC system components, and other building features (Weizhen et al. 1999). It may not always be possible or practical to increase the ventilation completely or mostly with outside air. In such cases, the effective ventilation rate per person can also be increased by limiting the number of people in the building in general or in certain rooms. Administrative practices that encourage remote participation and reduce room occupancy can help reduce risks from the SARS CoV-2 virus that causes COVID-19 (EPA 2021).

Large buildings such as schools rely on HVAC systems that supply fresh air from the outside. In recent years, HVAC systems have been designed to bring in less outdoor air to save energy. However, increasing the amount of outside air brought into buildings during a pandemic will reduce the amount of virus in the air, as it will reduce the amount of indoor air circulation. It must be ensured that HVAC systems are fully operational when people are in school buildings (Azimi and Stephens 2013). Ways to improve ventilation are: (a) bringing in as much outside air as possible, (b) ensuring HVAC settings maximize ventilation, (c) filtering and/or cleaning school air, and (d) using exhaust fans in restrooms.

Universities are more risky environments in terms of pandemics, as they are centers where people from different geographical regions gather. While necessary precautions will be taken on the university campus, it is inevitable that the classrooms should be designed to have distance and cleaning protection. In the arrangement of the classrooms, a straight-line order is generally applied and 4 m^2 of space per student is required due to the pandemic. When compared to normal conditions, it is seen that there is a significant increase in the cost of building classrooms per student.

The gross volume of the designed cross-row classroom is 500 m^3 and the volume per person is 17.24 m^3, with 28 students and 1 teaching staff. The capacity of the cross-row class is 38% higher than the straight-row class. Therefore, cross-row classrooms will likely require 38% less cost than straight-row classrooms.

The window area for natural lighting has been found to be a minimum of 31.5 m^2, and a design above this can be applied according to architectural criteria. It was seen that 71 piece TL-D 36 W/2500 lumen type fluorescent bulbs were required for the designed cross-row classroom, and the lamps were arranged as 28 fixtures, each of which was triple lamp. Naturally, since the volume of classrooms designed according to the Covid-19 pandemic is larger than the volume of classrooms under normal conditions, it will cause more lighting costs. This also applies to classroom construction costs.

Although the classrooms are designed in accordance with the pandemic criteria, it is especially important for the students and instructors who use these spaces to be careful about masks, distance and cleaning. In addition, the educational institution should prepare a checklist and establish a control team for the implementation of this guide (URL-4 2020). As a result, classrooms should be designed in accordance with pandemic conditions, face-to-face education and online education should be applied together. Pandemic-oriented classrooms should be flexible enough to be converted into normal classrooms when necessary.Even though the COVID-19 pandemic has ended, it is possible that similar epidemics will always occur, as it may be endemic in its continuation. Therefore, it is necessary to be prepared for pandemic, epidemic and endemic diseases.

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