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The Impact of Environmental Factors on Academic Performance of University Students Taking Online Classes during the COVID-19 Pandemic in Mexico

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Abstract: The COVID-19 pandemic and the quarantine period determined that university students (human resource) in Mexico had adopted the online class modality, which required them to adapt themselves to new technologies and environmental conditions that are different from classrooms at their university. Specifically, these new environmental conditions can be uncomfortable and have an impact on the students' academic performance. Consequently, the present study aims to determine the impact that the lighting, noise, and temperature levels (independent variables) have on academic performance (dependent variable) in university students during the COVID-19 pandemic. To do this, a questionnaire was developed, which was applied to 206 university students online, and a structural equation model was built that integrates the four variables through three hypotheses, which were statistically validated through the partial least squares method. Results showed that temperature, lighting, and noise have significant direct effects on university students' academic performance. As a conclusion, it was obtained that the three independent variables have an impact in the sustainability of university students (human resource).

Keywords: academic performance; COVID-19 pandemic; environmental conditions; lighting; Mexican universities; noise; online classes; structural equation model; temperature; university students

1. Introduction

Sustainability, in its socio-economic dimension, is defined as the capacity to efficiently use available resources (including human resources) guaranteeing that human well-being conditions (safety, health, education) are equally distributed among social classes and genres to ensure their profitability over time [1]. This definition implies that, for human resources, it is fundamental to provide an efficient design of the conditions in which they operate. An efficient design helps to improve their physical (such as strength, sight, hearing) and psychosocial (such as knowledge, motivation, creativity, socialization) factors, keeping them profitable over time. Then, this allows for sustainable development of the human resources. Additionally, ergonomics is a scientific discipline related to interactions between human beings and some elements from a specific system in a professional sense

applying theories, principles, information, and methods designing and optimizing human well-being and the entire system performance [2]. Specifically, the principal ergonomic objective is to preserve health and comfort as well as to provide safe conditions for human beings [3]. A healthy, comfortable, and safe environment helps improve employees' performance [4]. Regarding the relationship between ergonomics and sustainability, poor workspace design represents a risk factor for people, due to the uncomfortable conditions to which they are exposed, especially when they are forced to work for several hours in a row per day, affecting their well-being [5]. Poor design of a workspace cause people to be forced into uncomfortable body postures, which can lead to musculoskeletal disorders (MSDs). Ergonomic workstation design favors the sustainable development of workspaces and, consequently, people's performance [5]. Different authors, such as Nadadur and Parkinson [6] and Kim et al. [7], declared that ergonomic workstation designs are fundamental to enhance workspaces' sustainability and physical suitability. Also, ergonomic designs have a positive impact on sustainability because they improve the workstations' lifetime. Therefore, ergonomic design improves human resources' sustainability by facilitating its efficient use.

In Mexico, most of the research on ergonomics is focused on the manufacturing field [8–11]. However, there are other work sectors where people can also be exposed to different risks since there are no ergonomic design elements to interact with. Similarly, some conditions in the education sector may represent a risk not only for employees (teachers, administrators, directors) but also for students. For example, Parvez et al. [12] mentioned that constantly sitting on ill-fitting furniture and having a poor posture are causing students to suffer from different types of MSDs. Similarly, Aghahi et al. [13] conducted research to determine the effects of not considering ergonomic factors when designing suitable furniture and spaces for students. These authors found that up to 69% of students reported discomfort in their body; 23% of them had felt pain in hands and elbows, and 19% had experienced headaches. In the same way, other authors found that students may be exposed to ergonomic risks caused by environmental factors [14]. Also, Cochran Hameen et al. [15] mentioned a correlation among academic performance, young students' health, and the interior environment quality of their schools. Finally, Zhong et al. [16] mentioned that the absence of fresh air, or being exposed to extremely hot, cold, dry, humid conditions, loud noise, even a quiet room, and very bright or dark lighting, can negatively affect students' academic performance and attendance in their online classes. The previous information revealed that students can be exposed to uncomfortable and unsafe conditions in online classrooms, and their academic performance may be consequently affected.

In March 2020, the World Health Organization declared SARS-CoV-2 (COVID-19) coronavirus outbreak as a worldwide pandemic. This situation has caused employees from different companies and labor sectors around the world to work from home [17,18]. In Mexico, one of the main sectors in which their employees have been forced to work from home is the education sector [19]. In the country, there are 149,000 institutions that offer educational service [20] to 34,409,883 students [21] and hire 2,047,998 teachers [22]. Since March 2020, the education sector has been forced to teach online classes; therefore, students have been required to take online classes from a different location instead of their classrooms on a school campus [23]. This fact has led students to adapt to new conditions to take online classes and study. These conditions include environmental, technological, and psychosocial aspects. In addition, based on the research results mentioned above, these new conditions may impact the safety, comfort, health, and academic performance of students [24–29]. Similarly, exposure to diverse levels of noise [25,26], temperature [25,27], and lighting level [24,25] may cause distraction and discomfort to them. Besides, students have to interact with their new study station (computer, mouse, chair, table/desk, electrical outlets) which, if not designed from an ergonomic approach, can cause students' body segments to adopt forced or uncomfortable postures [25,28]. First, being exposed to these unpleasant postures can produce physical soreness and pain (in back, neck, legs, hands, fingers, wrists), possibly becoming MSDs [30]. Regarding psychosocial factors, online classes can increase mental workload or intellectual fatigue [29]. This increment is presented because the speed in which classes are taught online is fast. Another example is the learning and use of new and unfamiliar technological

applications (such as Classroom, Google Meet, Teams, Zoom, and Drive, among others) to fulfill their work in class or to complete tasks that teachers assign them. So far, there has been limited research about the impact that environmental conditions or factors (particularly noise, temperature, lighting) of online classes have on the academic performance of university students in Mexico. Consequently, the principal objective of the present study is to determine the impact of environmental conditions (lighting, noise, temperature) on the academic performance of university students who take online classes in Mexico. The document is structured in six sections: Section 2 addresses literature review about the impact that COVID-19 pandemic and environmental conditions (lighting, noise, temperature) have on the academic performance of university students; Section 3 presents the methodology that was implemented to acknowledge these environmental conditions' impact on the academic performance of students who take online classes in Mexico; Section 4 shows the results retrieved after the methodology was applied; Section 5 provides a discussion of the results obtained in this research by comparing them with the results obtained in previous studies. Finally, Section 6 is about the conclusions and a results discussion from the present study.

2. Literature Review

2.1. Influence of COVID-19 on University Students' Academic Performance

Several authors around the world have carried out research on the influence of COVID-19 on academic performance of university students. For instance, Gonzalez et al. [31] analyzed the effects of the COVID-19 confinement on the autonomous learning performance of students in higher education, specifically in the Universidad Autónoma de Madrid. To perform the analysis, these authors used a field experiment that included 458 students divided into two groups: the control group, and the experiment group. Students in the experiment group were those who took online classes as a consequence of the confinement. As a result, Gonzalez et al. [31] found that this confinement had a significant positive effect on the academic performance of students, which helped to improve students' learning strategies to a more continuous habit, improving their efficiency.

Similarly, Adnan and Anwar [32] studied the attitudes of college students in Pakistan towards online classes during the COVID-19 pandemic. To carry out their study, these authors surveyed undergraduate and postgraduate students. Students' perspectives revealed that, in underdeveloped countries like Pakistan, online classes cannot produce desired academic performance, since most students are unable to access the Internet. Moreover, these authors discovered that, during the COVID-19 pandemic, students face other problems, such as response time, absence of traditional classroom socialization, and lack of face-to-face interaction with the instructor. In other research, Demuyakor [33] analyzed the satisfaction level of Ghanaian international students in higher educational institutions in China during the COVID-19 pandemic. To collect data, this author employed an online survey focused on level of satisfaction of online learning and how Ghanaian international students were coping with this new situation. Results indicated that most of the students showed a positive attitude towards the implementation of online classes, even though they had to pay high costs to access the Internet with very slow connectivity.

In a fourth research, Haider and Al-Salman [34] compiled a data set to examine the psychosomatic impact of digital tools for online classes on Jordanian university students' well-being during the COVID-19 pandemic. These researchers designed a questionnaire survey that contained two main sections. The second section comprised five main constructs, including academic performance. Using the snowball sampling method, 775 students were surveyed. Most significant results indicated that 59.5% of students pointed out that face-to-face interaction contributes significantly to boosting their academic achievement, and 55.5% of them mentioned that the volume of assignments via e-learning led to confusion, frustration, and poor performance. In a worldwide research, and with a sample of 30,383 university students from 62 countries, Aristovnik et al. [35] analyzed how students perceive the impact of the COVID-19 pandemic in several factors affecting their lives at a global level. Their study

revealed that students were more satisfied with the support provided by teaching staff and public relationships of their universities. Also, these authors mentioned that deficient computer skills and the perception of a higher workload prevented students to perceive their own improved academic performance in the new teaching environment. Moreover, their research revealed that students with certain socio-demographic characteristics (male, part-time, first-level, applied sciences, a lower living standard, from Africa or Asia) were significantly less satisfied with their academic performance.

Additionally, Sintema [36] studied the effects of the COVID-19 pandemic on academic performance on students of secondary schools in Zambia. In his study, this author collected data from three professors (the head of Department for Mathematics, the head of Natural Sciences Department, and one science teacher) by means of semi-structured interviews via mobile phone. His results showed that there is likely to be a decrease in the percentage of students passing math tests if the COVID-19 epidemic is not contained in the shortest possible time.

To sum up, previous research has shown that during COVID-19 students from all over the world have had to adapt to the new conditions of universities, which can consequently have an impact on their academic performance.

2.2. The Impact of Lighting on University Students' Academic Performance

Several authors have defined academic performance as an exhibition of knowledge acquired or skills that are developed due to school subjects, which are evaluated through test scores or grades assigned by the teachers of subjects [37,38]. Explicitly, classroom lighting is a relevant aspect for students' academic performance, because lighting has a direct relationship with students' development [39]. Also, Oselumese et al. [39] mention that poor lighting leads to discomfort and poor academic performance. Specifically, there is research about the lighting level effects on students' academic performance. For instance, Hviid et al. [40] conducted a study to determine whether indoor lighting combined with ventilation influenced children's academic abilities or not. In their study, 92 children from 10–12 years old were involved. The authors measured processing speed, concentration, logical reasoning, and children's math solving abilities by applying a questionnaire as well as three different performance tests over four weeks. The experimental study was compared with another research, where a low and high ventilation rate (3.9 l/s and 10.6 l/s per person, respectively) was implemented; the lighting level impact on academic performance was also evaluated. It was found that when the lighting level constantly changed from warm light 2900 K-450 lux to a dynamic cool light 4900 K-750 lux with a steady correlated color temperature, the students' learning process speed, concentration, and math skills (6.6%, $p < 0.001$, 8.3%, $p < 0.001$, and 11.8%, $p < 0.006$, respectively) improved, and that when a high ventilation rate and a dynamic cool lighting were combined the academic performance increased too.

Other authors, such as Kudo et al. [41], conducted a study in non-electrified areas of North Bengal to study solar product effectiveness on children's academic performance. Results indicated that solar-based lights initially tended to increase school attendance, which decreased later. Although, the students' study hours and attendance initially improved, the academic performance did not improve. Similarly, Choi and Suk [42] investigated lighting color temperature impact on elementary students' academic performance. To do this, they experimented in a real-life environment with prolonged exposure in which they conducted three empirical studies to measure physiological responses as a potential mediator performance as well as to observe cognitive and behavioral responses during academic learning and playtime tasks. Results showed that for an easy, standard, and intensive activity, illumination levels of 3500 K, 5000 K, and 6500 K, respectively, are optimal. Also, Singh et al. [43] investigated the classroom lighting impact on 738 students' academic performance, who were selected through a systematic sampling technique. Particularly, to calculate the classroom lighting levels, the "Testo-545" lux meter was used, while students' academic performance was evaluated using the d2 Test of Attention to measure writing and reading speed and accuracy in academic tasks. Subsequently, these authors applied a questionnaire to obtain data and to evaluate students' perceptions towards the classroom lighting level. As a result, it was found that lighting had a significant impact on students'

concentration and academic performance ($p < 0.05$), and that lighting from 250 to 500 lux was associated with higher student concentration, which resulted in higher scores and improved students' academic performance. Finally, Gilavand et al. [44] investigated the educational classroom's lighting impact on elementary students' learning process and academic development. The sample was randomly selected, which was comprised of 210 students from Ahvaz, Iran. In their research, the Hermance achievement motivation and a self-constructed survey (an observation checklist that is used to measure physical parameters of the learning environment lighting level) were applied, along with face-to-face interviews with the students. In that case, it was found that educational classroom lighting has a meaningful impact on elementary students' learning process and academic performance ($p < 0.05$). Therefore, hypothesis H$_1$ is proposed:

Hypothesis 1 (H1). *The lighting level while taking online classes from home during the COVID-19 pandemic has a significant impact on university students' academic performance in Mexico.*

2.3. The Impact of Noise on University Students' Academic Performance

Literature offers different research addressing the effects that noise level can have on students' academic performance. For example, Braat-Eggen et al. [45] applied a questionnaire considering the acoustic parameters from five open studying environments in the Netherlands, in which correlations between noise disturbance and noisy sources that were perceived by students when performing scholarly tasks were investigated. Their research showed that when complex cognitive tasks, such as studying for a test, reading, or writing were performed, about 38% of the students were distracted by the noise and speech in the background in the open study environment. In another research, Batho et al. [46] examined the impact of ambient noises (speech and white noise) on the academic performance and difficulty scores tasks of youth with attention deficit hyperactivity disorder (ADHD) (N = 52). To observe and grade the reading performance, the oral count technique (reading precision) was required to register the time that was spent when reading tasks were done. Likewise, students' writing performance was assessed considering well-structured writing sequences (accuracy), and the total words that were written in an essay were considered. It was shown that white noise seems to improve students' reading time performance and writing competence, but their writing accuracy did not differ or improve at all. Similarly, Bulunuz et al. [47] evaluated students' opinions on noise level, its effects, and its control in two elementary schools (a public and a private school) in Turkey. Specifically, to collect the data, a 20-item questionnaire was applied to 432 students and some conducted noise measurements in schools were considered. Finally, students reported that they perceived a high noise level, however, the noise measurements revealed that the average noise level during recess for the private school was 74.56 dBA and for the public school was 82.18 dBA.

Likewise, Smith [48] examined the factors that influence the well-being and achievement of college students. Their study comprised a sample of 327 university students, who completed a survey to measure current exposure to some types of noise. Additionally, to assess students' welfare, a Student Well-Being Process Questionnaire (SWPQ) was applied, while to evaluate their academic performance course tasks and tests were considered to obtain their grade point average (GPA) score. As a result, this author found that the noise that was heard by the students was not directly linked to their well-being or academic achievement. Additionally, Bhang et al. [49] analyzed how high-pitched noise impacted on the students' cognitive functions, which is linked to students' learning performance. In fact, to conduct their research, 268 students from three different elementary schools in Ulsan, Korea were included: 135 boys and 133 girls, ranging from 10 to 12 years old. Also, as it was reported on the students' testing conditions (background noise versus additional noise) they were separated into two different groups, where they had to perform tests using psychological examination tools. Thus, noise significantly affected the students' continuous performance, the large-scale IQ, the verbal IQ, children's Stroop, and the color trace test scores. Finally, agreeing with Oselumese et al. [39], schools located on noisy urban streets are more prone to have mental concentration deficits, which leads to poor student performance.

Other authors who have investigated the impact that the noise level has on the students' academic performance are: Shield and Dockrell [50,51], Cook et al. [52], Klatte et al. [53], and Xie et al. [54], among others.

Therefore, hypothesis H$_2$ is proposed.

Hypothesis 2 (H2). *The noise level while taking online classes from home during the COVID-19 pandemic has a significant impact on university students' academic performance in Mexico.*

2.4. The Impact of Temperature on University Students' Academic Performance

Noise and lighting are aspects that impact on students' performance; similarly, there are several studies showing that temperature has impacted on university students' academic performance. For example, Baafi [55] mentioned that classroom temperature impacted on students' academic performance. For instance, López-Chao et al. [56] mentioned that low-temperature levels tend to distract students and make them more alert, which increases their nervous activity preparing the mind for action. On the other hand, hot environments negatively affect their performance in comparison with thermally neutral environments. Monguno et al. [57] studied over three years the ambient temperature impact on 259 randomly selected students' academic performance from the Kashim Ibrahim College of Education. Also, the student achievement after each evaluation period roughly coincided with hot and cold seasons. In fact, to measure students' perceptions towards achievement in both seasons, Monguno et al. [57] applied questionnaires after the third year. Some differences were found from both hot and cold seasons impacting on the students' performance in the first and third year; however, significant differences could not be retrieved from the second year.

Additionally, Phan [58] examined the potential impact that gender has on thermal perception and academic performance. This author hypothesized that women would experience an increment in academic performance as the temperature increased, while men would experience the opposite effect. Specifically, for the previous hypothesis testing, a quasi-experimental design was implemented, while data was collected through a Google form that registered gender and had 24 SAT-style questions. The author repeated this process on three different days using the same classroom, where the temperature was manipulated at 67 °F, 72 °F, and 78 °F each day; a correlation between thermal perception and academic performance ($p = 0.049$) was shown. Also, it was concluded that men's academic performance increased as the temperature raised, while the women's academic performance was boosted as the temperature decreased. In another study, Wargocki and Wyon [59] conducted two experimental studies in school classrooms during summer. In both studies, the air temperature was manipulated using split cooling units running or idling for a week. Students solved between six and eight exercises that exemplify some schoolwork aspects; afterwards, students' environmental perceptions and at what level any symptom was experienced were shared on visual analogue scales. Results showed that the students' performance improved considerably in two numerical tests and in two language-based exams if the temperature decreased from 25 °C to 20 °C (77 °F to 68°F, respectively). Also, when the outdoor air increased by 5.2 to 9.6 L/s, the students' performance improved significantly on four numeric exercises. Likewise, Haverinen-Shaughnessy and Shaughnessy [60] analyzed the relationship with the temperature level impact on students' academic performance (N = 3109) who were from a school district integrated by 70 elementary institutions (140 fifth-grade classrooms) in Southwestern United States. The previous study was conducted to know the temperature impact on academic performance. In conclusion, these authors found that students increased their average math scores from 12 to 13 points per Celsius that were decreased from 25 °C to 20 °C temperature. In conclusion, classroom thermal comfort significantly enhances students' academic performance. Finally, in the literature regarding thermal quality and students' learning, Earthman [61] suggested that there are optimal temperature ranges for optimal learning results. This author declares that 20 °C and 24 °C (68 °F and 74 °F, respectively) temperatures are more appropriate for students' learning and comfort. Therefore, hypothesis H$_3$ is proposed:

Hypothesis 3 (H3). *The temperature level while taking online classes from home during the COVID-19 pandemic has a significant impact on university students' academic performance in Mexico.*

Figure 1 shows the hypothetical causal model from the present study.
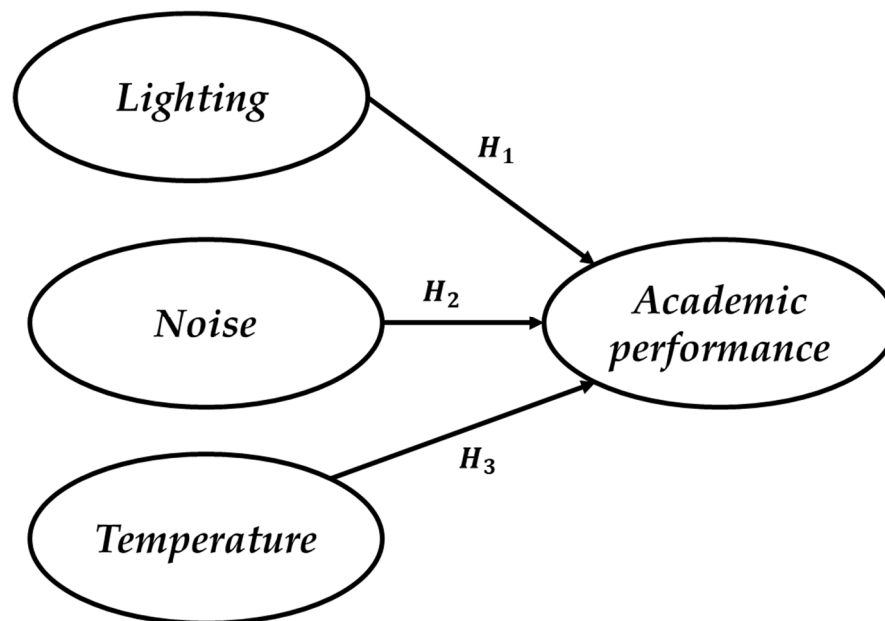

Figure 1. Hypothetical causal model.

3. Methodology and Data

For the present study, a cross-sectional survey design was used. The methodology that was applied is divided into three sections: (1) Questionnaire development, (2) questionnaire application, and (3) data statistical analysis.

3.1. Questionnaire Development

The literature presents several studies that deal with environmental conditions (lighting, noise, temperature) impacting on students' academic performance. In several studies, data has been collected through a questionnaire. For example, Hviid et al. [40] applied a questionnaire divided into three different sections. The first section addressed the general students' welfare at and out of school. The second section included eight questions about indoor environment perceptions from the classroom (temperature, air sensation, air quality, noise, lighting). The third section asked students to rate their motivation considering: headache, concentration difficulty, fatigue, effort, and well-being. Similarly, Singh et al. [43] applied a questionnaire that was divided into eight sections, where three belonged to the indoor temperature, noise, and lighting perception by students. Also, López-Chao et al. [56] applied the Indoor Physical Environment Perception scale (iPEP scale), which was adapted using the Student Perception Questionnaire of Learning Space to observe the learning space design from different classrooms at a university. Other authors, who also applied questionnaires to obtain data and examine the lighting, noise, or temperature impact on academic performance, are Gilavand et al. [44], Braat-Eggen et al. [45], Bulunuz et al. [47], Smith [48], and Monguno et al. [57], among others. However, these questionnaires were not designed to obtain data on environmental conditions (lighting, noise, and temperature) where higher education students interact with when taking online classes because of the COVID-19 worldwide pandemic. Moreover, according to previous antecedents, the Questionnaire of Effects from Online Classes in university students' health and academic performance (QEOC) is created. The QEOC is divided into eight different sections: (1) Introduction, (2) demographics, (3) environmental

factors, (4) technological factors, (5) motivation, (6) academic performance, (7) mental workload, and finally, (8) effects of online classes on students' health. Since the present study's elemental objective is to identify how environmental factors impact on students' academic performance, only sections (3) and (6) were included. To develop the questions for both sections, a literature review was done to find research including items regarding how the independent variables (lighting, noise, and temperature) impact the dependent variable (students' academic performance). The literature review was performed in some databases, such as Ebscohost, Taylor and Francis, Emerald, ScienceDirect, and SAGE Journals, among others. The main keywords were "lighting", "noise", "temperature", "academic performance", "school", and "students". The literature review represents a rational validation to develop the previous questionnaire [62].

Once items were selected, they are tailored to be applied to an online classroom context where students take classes outside of the educational institution classrooms. Table 1 shows the items and references that they were adapted to.

Table 1. Reference for items of the Questionnaire of Effects from Online Classes on health and academic performance of university students (QEOC).

Variable	Item	Reference
Lighting	The level of lighting in my study area allows me to see clearly what is around, as well as to concentrate when taking online classes.	[63]
	I can control the level of lighting in my study area when taking online classes (for example: opening/closing blinds, curtains; having a table lamp; dimmers within reach).	[64]
	The level of lighting (from lamps, computer screen) in my study area allows me to have visual comfort when taking online classes.	[65]
Noise	I have privacy in my study area when taking classes online.	[66]
	The noise level (coming from devices, people's talks, external sources) in my study area allows me to concentrate, take the class, and clearly hear my teacher and classmates.	[67]
	I can control the noise level in my study area (example: opening/closing doors/windows).	[64]
Temperature	The temperature in my study area allows me to be comfortable and concentrate when taking online classes.	[67]
	I can control the temperature in my study area (for example: opening/closing windows, turning ventilators on/off) when taking online classes.	[64]
	The air quality in my study area is appropriate for taking the classes online.	[66]
Academic performance	By taking online classes I can do all my activities successfully.	[68]
	By taking classes online I can organize my time to do everything the teachers ask me to do.	[68]
	By taking online classes my grades improve.	[68]
	I have acquired more knowledge by taking online classes.	[69]
	I have improved my communication skills by taking classes online.	[69]
	I have improved my teamwork skills by taking classes online.	[69]
	Online classes improve my creativity	[70]
	I am satisfied with the results that I have obtained by taking classes online.	[70]

Source: Developed by authors.

After questions were created, they were registered in a Google form. The QEOC must be answered through the five-point Likert scale, where 1 = Never, 2 = Hardly ever, 3 = Sometimes, 4 = Usually, and 5 = Always. This scale is implemented, since it has been used in recent and similar studies [62,71,72].

3.2. Application of the Questionnaire of Effects from Online Class (QEOC) Questionnaire and Participants

Once this research was approved by the institutional review board (IRB), students who have taken online classes during the COVID-19 pandemic from 12 different universities in Mexico were required

to answer the QEOC questionnaire. It did not matter if they were undergraduate or graduate students. The QEOC application was done online, therefore the following steps were necessary:

(1) Searching for teachers from universities in Mexico: To contact teachers, first, it was necessary to look for publications, from conferences, magazines, book chapters, and other sources in which authors were affiliated with a university in Mexico and their name and email were available to contact them.

(2) Teachers and students sampling: After the list of teachers with their institutional emails was obtained, an email was sent explaining the project and its objective. Also, the QEOC link was shared with them in which participants were encouraged to distribute it among students and other teachers at their university, or even with teachers from other universities in the country. Other students were contacted through virtual platforms such as Classroom or Facebook.

The QEOC questionnaire was available online from July to October 2020. All students participated voluntarily. The research conforms to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh 2000) [73], and all ethical guidelines were followed as required for conducting human research, including adherence to the legal requirements of Mexico. A total of 500 surveys were distributed, but 206 were completed, which represents a response rate of 45.5%. These 206 valid surveys were compiled and used to analyze the data. To collect the data, the convenience sampling method was used, since it has high feasibility and low cost [74,75]. This sampling method is a non-probabilistic method which consists that people answer the questionnaire when they have available time [75,76]. Moreover, as mentioned before, participation of all students was voluntary, it was difficult to apply the QEOC face-to-face, and students had low time availability. As a consequence, not all the contacted teachers and students answered the QEOC. Then, from some universities, only one student answered the QEOC, whereas from other ones there was no answer. According to Kock [77], for a minimum path coefficient of 0.197, a significance level of 0.05, and a statistical power of 0.8, the minimum sample size is 160. This author mentions that this sample size also applies when researchers are uncertain about the results they should expect from their studies, as in this research.

Most of the surveyed students were in the range of >20–30 years old (71.36%), 56.80% were male, and 88.83% were in single marital status. Table 2 shows the socio-demographic characteristics of the surveyed students. Similarly, Table 3 illustrates the students that were surveyed per university. The university where students participated the most was the University A, which had 90 participants. All students belonged to public universities.

3.3. Data Statistical Analysis

The data statistical analysis addresses the QEOC statistical validation and the analysis from the relationships between variables. The data analysis validates the three hypotheses that were proposed in Section 2.

3.3.1. Statistical Validation of the QEOC Questionnaire

The database was created and registered in the SPSS 24® software [62,78], substituting the median by the outliers or missing values, since the data is collected on an ordinal scale (Likert scale) [62,79].

Subsequently, statistical validation is performed for each variable of the QEOC using as a reference of 0.7, which is the minimum acceptable value from the Cronbach's alpha coefficient [62]. Then, variables with a correlation under 0.3 are eliminated, because a variable is only integrated and considered when the Cronbach's alpha coefficient is over 0.7. Furthermore, for the discriminant validity and convergent validity, the average variance extracted (AVE) measure is used. For the convergent validity, it is required that the AVE is over or equal to 0.5 in each element, while the *p*-value has to be significant in each variable [62]. Similarly, the variance inflation factor index (VIF) measure is implemented to determine the collinearity level between variables, which exists as long as the VIF value is under 3.3 in each variable [80]. Finally, the data is arranged on an ordinal scale, where the Q^2 coefficient serves as a non-parametric

measure of predictive validity, which is achieved only when the Q^2 value is over 0.2 [62,80]. Q^2 coefficient is provided only for endogenous latent variables [77]. In this research, the endogenous latent variable is academic performance.

Table 2. Socio-demographic characteristics of the surveyed students.

Socio-Demographic Characteristics of Surveyed Students	
Age	**Number (%)**
>18–20	44 (21.36%)
>20–30	147 (71.36%)
>30–40	12 (5.83%)
>40–50	3 (1.46%)
Gender	
Male	117 (56.80%)
Female	89 (43.20%)
Marital status	
Single	183 (88.83%)
Married	13 (6.31%)
Free union	9 (4.37%)
Other	1 (0.49%)

Source: Developed by authors.

Table 3. Surveyed students per university.

Number of Surveyed Students	University											
	A	B	C	D	E	F	G	H	I	J	K	L
	90	85	11	8	3	2	2	1	1	1	1	1

Source: Developed by authors.

3.3.2. Analysis of the Structural Equation Modeling

To evaluate the relationships among the variables that are depicted in Figure 1, WarpPLS 6.0® software is used, which integrates the structural equation modeling (SEM). This software also includes the partial least squares (PLS) method, since it is useful when the analyzed data is on an ordinal scale and represents a small sample that does not comply with the normality requirements [62,81]. Several efficiency indexes are used before interpreting the model: The average path coefficient (APC), the average R-squared (ARS), and the average adjusted R-squared (AARS), which are associated with a *p*-value that is significant when it is under 0.05. Moreover, the average block VIF (AVIF) and the average full collinearity VIF (AFVIF) indexes are used, which must be under 5. Furthermore, the Tenenhaus index (GoF) is included, which must be over 0.25 [82].

Additionally, the direct, the indirect, and the total effects must be measured among variables in an SEM. First, the direct effects allow the model hypotheses validation (Figure 1), which are represented with an arrow. Second, the indirect effects measure the relationship among two variables through mediating variables, using two or more segments between an independent latent variable and a dependent latent variable. Finally, the total effect is the sum of the direct and indirect effects [82]. Indirect effects are not presented in Figure 1 since there is only one segment between each of the three independent variables and the dependent variable; therefore, the total effects are equal to the direct effects.

Notably, the direct effects are exemplified through the letter *β*; a standardized parameter from the relationship measurement in two variables that is expressed in standard deviations, and it is associated with a *p*-value that determines whether a variable relationship is statistically significant or not with a 95% confidence interval [62].

Finally, the size effect (SE) is estimated for each effect. The SE allows acknowledging the explanatory power; the capacity to classify the contribution that an independent variable has on each dependent variable, therefore, the size effect is a decomposition of R^2 [62].

4. Results

4.1. Descriptive Analysis of the Data

Table 4 presents the data descriptive analysis of the dependent and independent variables and their corresponding items. Note that for the three independent variables, most of the students answered 3 = Sometimes, 4 = Usually, or 5 = Always. However, note that in the dependent variable of academic performance, the most frequent answer was 3 = Sometimes. This result suggests that environmental conditions at home are not optimal and that there are other variables that can affect academic performance.

Table 4. Descriptive analysis.

Variable	Item	Answer	Frequency (%)	Mean	Median	Standard Deviation
Lighting	The level of lighting in my study area allows me to see clearly what is around, as well as to concentrate when taking online classes.	1 2 3 4 5	2 (1%) 5 (2.4%) 49 (23.8%) 91 (44.2%) 59 (28.6%)	3.97	4	0.843
	I can control the level of lighting in my study area when taking online classes (for example: opening/closing blinds, curtains; having a table lamp; dimmers within reach).	1 2 3 4 5	10 (4.9%) 10 (4.9%) 34 (16.5%) 60 (29.1%) 92 (44.7%)	4.04	4	1.117
	The level of lighting (from lamps, computer screen) in my study area allows me to have visual comfort when taking online classes.	1 2 3 4 5	2 (1%) 16 (7.8%) 49 (23.8%) 78 (37.9%) 61 (29.6%)	3.87	4	0.959
Noise	I have privacy in my study area when taking classes online.	1 2 3 4 5	20 (9.7%) 34 (16.5%) 50 (24.3%) 46 (22.3%) 56 (27.2%)	3.41	3	1.306
	The noise level (coming from devices, people's talks, external sources) in my study area allows me to concentrate, take the class, and clearly hear my teacher and classmates.	1 2 3 4 5	13 (6.3%) 34 (16.5%) 74 (35.9%) 66 (32%) 19 (9.2%)	3.21	3	1.033
	I can control the noise level in my study area (example: opening/closing doors/windows).	1 2 3 4 5	18 (8.7%) 36 (17.5%) 53 (25.7%) 57 (20.4%) 42 (20.4%)	3.33	3	1.229
Temperature	The temperature in my study area allows me to be comfortable and concentrate when taking online classes.	1 2 3 4 5	10 (4.9%) 17 (8.3%) 55 (26.7%) 61 (29.6%) 63 (30.6%)	3.73	4	1.128
	I can control the temperature in my study area (for example: opening/closing windows, turning ventilators on/off) when taking online classes.	1 2 3 4 5	12 (5.8%) 17 (8.3%) 36 (17.5%) 73 (35.4%) 68 (33%)	3.82	4	1.154
	The air quality in my study area is appropriate for taking the classes online.	1 2 3 4 5	4 (1.9%) 12 (5.8%) 51 (24.8%) 67 (32.5%) 72 (35%)	3.93	4	1.002

Table 4. *Cont.*

Variable	Item	Answer	Frequency (%)	Mean	Median	Standard Deviation
Academic Performance	By taking online classes I can do all my activities successfully.	1 2 3 4 5	12 (5.8%) 23 (11.2%) 67 (32.5%) 64 (31.1%) 40 (19.4%)	3.47	4	1.103
	By taking classes online I can organize my time to do everything the teachers ask me to do.	1 2 3 4 5	11 (5.3%) 25 (12.1%) 67 (32.5%) 56 (27.2%) 47 (22.8%)	3.50	3.50	1.129
	By taking online classes my grades improve.	1 2 3 4 5	13 (6.3%) 27 (13.1%) 72 (35%) 62 (30.1%) 32 (15.5%)	3.50	3	2.395
	I have acquired more knowledge by taking online classes.	1 2 3 4 5	27 (13.1%) 54 (26.2%) 68 (33%) 39 (18.9%) 18 (8.7%)	2.84	3	1.143
	I have improved my communication skills by taking classes online.	1 2 3 4 5	27 (13.1%) 48 (23.3%) 65 (31.6%) 23 (20.9%) 23 (11.2%)	3.05	3	2.167
	I have improved my teamwork skills by taking classes online.	1 2 3 4 5	29 (14.1%) 49 (23.8%) 66 (32%) 39 (18.9%) 23 (11.2%)	2.88	3	1.191
	Online classes improve my creativity	1 2 3 4 5	29 (14.1%) 49 (23.8%) 62 (30.1%) 43 (20.9%) 23 (11.2%)	3.03	3	2.177
	I am satisfied with the results that I have obtained by taking classes online.	1 2 3 4 5	28 (13.6%) 33 (16%) 68 (33%) 42 (20.4%) 35 (17%)	3.24	3	2.370

Source: Developed by authors.

4.2. Validation of Variables

Table 5 shows the QEOC questionnaire had sufficient internal and content validation, because the composite reliability and Cronbach's alpha were over 0.7 in each variable. Also, if an item were removed from the QEOC, the Cronbach's alpha value would decrease for the corresponding variable. Then, all items were kept in the QEOC. Similarly, Table 6 introduces the indexes' results that validate the dependent and independent variables mentioned in the present study, which comply with the minimum acceptable requirements. Also, the predictive validity was obtained, since the adjusted R^2 and the R^2 were over 0.2. According to these validation results, these variables can be integrated into a SEM to be analyzed.

Table 5. Validation of variables and items.

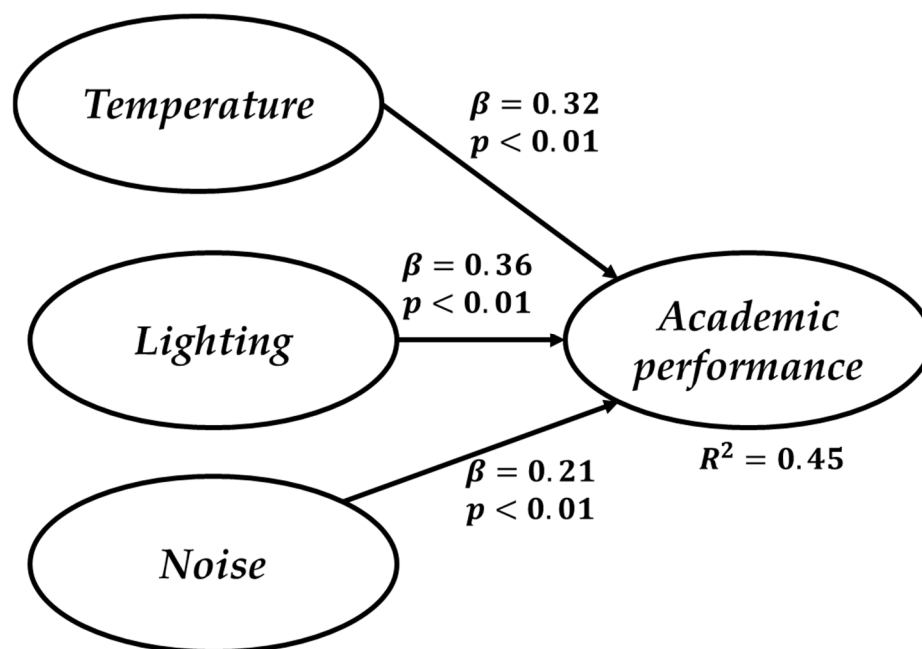| Variables and Their Items	Cronbach's Alpha	Cronbach's Alpha if the Item is Removed from QEOC
Lighting	0.776	
The level of lighting in my study area allows me to see clearly what is around, as well as to concentrate when taking online classes.		0.698
I can control the level of lighting in my study area when taking online classes (for example: opening/closing blinds, curtains; having a table lamp; dimmers within reach).		0.726
The level of lighting (from lamps, computer screen) in my study area allows me to have visual comfort when taking online classes.		0.643
Noise	0.816	
I have privacy in my study area when taking classes online.		0.743
The noise level (coming from devices, people's talks, external sources) in my study area allows me to concentrate, take the class, and clearly hear my teacher and classmates.		0.766
I can control the noise level in my study area (example: opening/closing doors/windows).		0.712
Temperature	0.871	
The temperature in my study area allows me to be comfortable and concentrate when taking online classes.		0.787
I can control the temperature in my study area (for example: opening/closing windows, turning ventilators on/off) when taking online classes.		0.843
The air quality in my study area is appropriate for taking the classes online.		0.815
Academic performance	0.830	
By taking online classes I can do all my activities successfully.		0.759
By taking classes online I can organize my time to do everything the teachers ask me to do.		0.760
By taking online classes my grades improve.		0.751
I have acquired more knowledge by taking online classes.		0.751
I have improved my communication skills by taking classes online.		0.776
I have improved my teamwork skills by taking classes online.		0.756
Online classes improve my creativity		0.791
I am satisfied with the results that I have obtained by taking classes online.		0.738

Source: Developed by authors.

4.3. Structural Equation Modeling

Figure 2 presents the model evaluation results obtained, where β-values represent the direct effects from the relationships among the variables that have been mentioned, while their corresponding *p*-value indicates their relationship significance. Additionally, the broken arrow indicates that the hypothesis is rejected, while continuous arrows express that the hypotheses are not rejected. Similarly, the R^2 is the measurement of the variance explained by the independent variables over the dependent variable.

Table 6. Validation of variables.

Indexes	Lighting	Noise	Temperature	Academic Performance
R-squared				0.45
Adjusted R-squared				0.44
Composite reliability	0.870	0.891	0.921	0.872
Cronbach's alpha	0.776	0.816	0.871	0.830
Average Variance Extracted (AVE)	0.691	0.731	0.795	0.766
Variance Inflation Factor index (VIF)	1.643	1.605	1.589	1.288
Q-squared				0.239

Source: Developed by authors.

Figure 2. Model evaluation.

4.3.1. Validation of the Model

Table 7 contains the model validation indexes' results. Specifically, the outcomes showed that each index complies with the minimum or maximum requirements that were defined in the methodology section. Therefore, collinearity problems among the variables were presented, which demonstrate that the model has predictive validity, and the data is appropriate.

Table 7. Validation of variables.

Indexes	Value	*p*-Value	Acceptable If
Average path coefficient (APC)	0.191	<0.001	*p*-value ≤ 0.05
Average R-squared (ARS)	0.239	<0.001	*p*-value ≤ 0.05
Average adjusted R-squared (AARS)	0.228	<0.001	*p*-value ≤ 0.05
Average block VIF (AVIF)	1.561		AVIF ≤ 3.3
Average full collinearity VIF (AFVIF)	1.531		AFVIF ≤ 3.3
Tenenhaus (GoF)	0.401		GoF ≥ 0.36

Source: Developed by authors.

4.3.2. Direct Effects

Table 8 presents the (β) values representing each direct effect and the corresponding *p*-value for significance. If the *p*-value for the direct effect was under 0.05, it was accepted as significant. According to hypotheses H$_2$ and H$_3$, the *p*-value is under 0.05, consequently, it is decided to accept them; however, hypothesis H$_1$ was rejected because the *p*-value was over 0.05. Also, the greatest impact for the dependent variable is from the noise variable, which is the variable that critically impacts the most on the academic performance of university students who are taking online classes during the COVID-19 pandemic in Mexico.

Table 8. Decision to accept or reject the proposed hypotheses.

H$_i$	Independent Variable	Dependent Variable	β	*p*-Value	Decision
H$_1$	Lighting	Academic Performance	0.36	<0.001	Not Rejected
H$_2$	Noise	Academic Performance	0.21	<0.001	Not Rejected
H$_3$	Temperature	Academic Performance	0.32	<0.001	Not Rejected

Source: Developed by authors.

Table 8 portrays the results of each hypothesis, where the following was obtained:

H1: *There was enough statistical evidence to declare that lighting level while taking online classes from home during the COVID-19 pandemic has a significant impact on the university students' academic performance in Mexico, since when the lighting level standard deviation increases in one unit, the university students' academic performance standard deviation increases in 0.36 units.*

H2: *There was enough statistical evidence to establish that noise level while taking online classes from home during the COVID-19 pandemic has a significant impact on the university students' academic performance in Mexico, since when the noise level standard deviation increases in one unit, the university students' academic performance standard deviation increases in 0.21 units.*

H3: *There was enough statistical evidence to establish that temperature level while taking online classes from home during the COVID-19 pandemic has a significant impact on the university students' academic performance in Mexico, since when the temperature level standard deviation increases in one unit, the university students' academic performance standard deviation increases in 0.32 units.*

Specifically, for the dependent variable (academic performance) a R^2 value equal to 0.45 was obtained, which declares that the independent variables (lighting, noise, and temperature) explained this dependent variable at 45%, where 26.8% corresponds to the noise variable, 11.3% to the temperature variable, and 6.9% to the lighting variable.

5. Discussion

The results obtained in this research make it clear that the academic performance of university students can be affected by the environmental conditions, which they are exposed at home during the COVID-19 pandemic, and this is supported by previous studies. In the specific case of lighting, these results are like those obtained by other authors. For example, Oselumese et al. [39] highlight that the level of lighting directly affects the academic performance of students. In fact, these authors mentioned that students cannot study unless the level of lighting is adequate. This also applies to students who take classes online.

Likewise, the results of this research come to support the results of Hviid et al. [40], who also mentioned that a good level of lighting, in conjunction with proper ventilation, helps to improve the academic performance of students. On the other hand, when the improvements in lighting levels inside the house are relatively scarce, it is insufficient to improve the academic performance of students, as pointed out by Kudo et al. [41]. In fact, Singh et al. [43] indicated that lighting levels between 250

and 500 lux are adequate for better school performance. This makes it clear that the level of lighting has a significant impact on academic performance, as mentioned by Gilavand et al. [44].

In the case of the noise variable, the discussion is similar. For example, in their study, Braat-Eggen et al. [45] found that noise was distracting for students when they were performing cognitive tasks. This also applies to Mexican students who take online classes, since they are exposed to a higher level of noise at home, and therefore, a higher level of distraction when taking online classes from home. This comes to support the result obtained in this investigation. On the other hand, the study carried out by Batho et al. [46] makes it clear that variations in noise level impact students' reading and writing, which in turn ends up impacting their academic performance. In fact, Bulunuz et al. [47] mentioned that a healthy school climate favors the academic development of students. So, noise pollution negatively impacts their learning. Finally, the results of this research coincide with those obtained by both Bhang et al. [49] and by Oselumese et al. [39], in the sense that in both studies the results indicated that the noise level impacts the academic performance of students.

Finally, regarding temperature, the results obtained in this research also coincide with those obtained in previous studies in the fact that this variable influences the academic performance of students. Proof of this is found in a recent study, where Baafi [55] detected that the temperature of the classrooms had an impact on academic performance. These results also coincide with those obtained by López-Chao et al. [56]. This is since these authors detected that low levels of temperature as well as hot environments, negatively appreciate the academic performance of students, compared to thermally neutral environments. Similarly, as in this research, Phan [58] detected that there is a correlation between thermal perception and academic performance. In turn, this coincides with what was obtained by Wargocki and Wyon [59], and Haverinen-Shaughnessy et al. [60], who found that student performance improves if temperature drops from 25 to 20 °C (77 °F to 68 °F). In fact, Earthman [61] found that temperature levels between 20 to 24 °C (68 °F to 74 °F) are ideal for improving student comfort and academic performance so that temperature levels outside this range have a negative impact on their performance.

All these previously conducted studies theoretically support the results obtained in this investigation, which were also statistically substantiated. The difference is that the previous studies were not carried out in a pandemic period with a sample of Mexican students.

With respect to the words sustainability and students, the literature provides different studies that deal with them. However, most of these studies focus on how universities teach topics of sustainability and the understanding level of students with respect to this topic. For instance, and to name few, Iyer-Raniga et al. [83] performed a study to investigate whether students are aware of the importance of sustainability education in their working lives and whether there are any differences in the way students in Melbourne and Singapore view sustainability education. Similarly, Okręglicka [84] carried out a diagnosis of the current student commitment to the sustainability developed by higher education system and its influence on intention to apply the principles of sustainable development in the future.

Some studies, that are related to sustainability of university students as human resources, are those developed by Maragakis et al. [85] and by Surjanti et al. [86]. In the case of Maragakis et al. [85], these authors propose three metrics that can be used to assess the economic sustainability of students graduating higher education. On the other hand, Surjanti et al. [86] analyzed whether self-efficacy and self-concept significantly affect the sustainability of university students through participatory ecological learning. Finally, Poza-Vilches [87] state that all members of the educational community have a relevant role in the development of professional competences on the sustainability of students. These authors provided several competences to be applied in the teaching–learning process that allows the promotion of an education for sustainability.

Regardless of the results they have obtained and although these previous studies deal with strategies to favor the sustainability of university students, none of them is made from an ergonomic approach considering environmental factors. This highlights the novelty of this research and makes it clear that there is a wide field of research on the topics of ergonomics and sustainability of students who take online classes.

6. Conclusions

Three hypotheses were statistically tested to analyze the relationship among three environmental variables (lighting, noise, and temperature) and the academic performance of university students who take online classes during the COVID-19 pandemic in Mexico. The present study analysis and results show that the three environmental variables have an important role in the academic performance of university students who take online classes in Mexico, implying these variables influence students' academic performance, concentration, and comfort. Consequently, their grades and learning process can be affected. In turn, their motivation to continue with their studies can be impacted as well. Similarly, sustainability in its socioeconomic dimension implies that human well-being conditions (such as study area design), must be provided to efficiently use the human resources [1], such as university students. Therefore, a study area design in which environmental variables are uncomfortable and cannot be controlled tend to negatively affect the effective human resource sustainability, in this particular case, academic performance of university students is the aspect that is affected.

Also, in the present study, it is acknowledged that college students' academic performance does not depend exclusively on the time they spend learning or memorizing information, but on other variables. Therefore, under normal conditions, i.e., classes taken in facilities of universities, each higher education institution must encourage to offer classes providing an educational environment that is comfortable enough for students, that is, where the lighting, noise, and temperature environmental variables can be controlled within classrooms, since they improve the human resource sustainability; specifically, the college students' academic performance, and as a result, the institution sustainability will be increased. In conditions of online classes, several suggestions may be considered. For instance, it is suggested that professors do not assign homework to their students. This helps to reduce the time students spend in front of a computer. In this way, the mental workload that this can cause can be reduced as well as the time of exposure to non-optimal environmental conditions. On the other hand, it is also suggested that more interactive classes be implemented. This can be done through game-based learning [88,89], since it promotes learning through an entertaining way and fosters student motivation to increase engagement in the educational process [90]. Similarly, it is recommended that each student have a private place at home while taking classes online to reduce exposure to high levels of distracting noise.

All these situations can cause university students to not achieve optimal learning, which can also inhibit their sustainable development as human resource.

According to the direct effect results retrieved from the impact of three environmental variables on the academic performance analysis, the following theoretical and managerial implications were considered:

- University students' academic performance not only relies on the time students spend learning or memorizing information, since their development is also affected by other variables.
- A private space may help to decrease the noise level perceived by the students and then, it may help to improve their academic performance while taking online classes at home.
- An ergonomically designed study area for online classes, such as quiet space, temperature-controlled rooms, to mention a few, can help improve the students' and the higher education institutions' sustainability.

7. Further Research

It is remarked that the COVID-19 pandemic has impacted on the academic performance of university students who take online classes in Mexico. However, this academic performance can be affected by other variables different to the lighting, noise, and temperature levels. Such variables can include the desk/table and chair design where students take classes on, or the technological devices they are using (tablet, cell phone, computer) to study, and the time they interact with these furniture and equipment. If the design of these furniture and equipment is not ergonomic, students may suffer from pain in different body parts such as back, neck, arms, and wrists. Also, these variables may increase the students' mental workload, which can cause stress, anxiety, headache, among other

effects. All these effects may impact on students' academic performance influencing their motivation to continue studying and learning. All these variables are detailed in the QEOC questionnaire.

However, the COVID-19 worldwide pandemic has not affected only university students, but also higher education teaching institution staff, whose job performance may consequently affect their sustainability. Therefore, for further research, different analyses can be carried out on the variables mentioned in this study and include other variables that could affect online learning, in addition to combining both the perceptions of university students and teachers.

Conflicts of Interest: The authors have declared that there is no conflict of interest.

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