Analysis of the Academic Performance of the Students of Tertiary Level on Consumption of Excess CO_2: A Case Study on Advanced Technological Institute of Batticaloa.

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ABSTRACT

Clean breathing plays a huge role in our healthy well-being. When we inhale polluted air, it causes numerous unhealthy conditions for people. Indoor air is polluted by several factors, in which carbon dioxide (CO_2) plays a huge role. CO_2 and bio-effluents are natural products of human metabolism, but high CO_2 levels can result in unhealthy symptoms such as sore throat, irritated nose/sinus, combined mucous membranes, tight chest, wheezing, and low performance in academic activities. In a closed room where most people sleep (especially middle- and poor-class families) on the floor without using a bed, there is a high possibility of inhaling a high amount of CO_2. Ventilation is important to expel indoor-generated pollutants from indoor air or reduce their concentration to satisfactory levels. But ventilation and excess CO_2 are significant challenges to those who are middle-class and poor. The purpose of this study is to suggest a bearable ventilation solution to the students who are suffering from respiratory diseases due to excessive CO_2 and help them achieve good academic performance.

For this research study, a stratified sampling method is used to analyze the collected data. Advanced Technological Institute (ATI) Batticaloa, functioning under the Sri Lanka Advanced Technological Institute (SLIATE), is the geographical boundary for this research study. The population for this study includes the students who had low academic performance in the Advanced Technological Institute (ATI) Batticaloa. Initially, the simple random sampling method is applied for selecting 100 samples from the proposed population using secondary data (results published by the Exam Department-SLIATE). Then, 30 samples were selected among 100 samples for our study based on the following criteria using a closed questionnaire: Students should have pulmonary disease; families in which more than three occupants are sleeping together; the bedrooms of their families have very little or no ventilation. Thereafter, an automated ventilation system was fixed inside their bedrooms. The academic performance of the same students was re-examined after ensuring that their health was properly maintained. The analysis of exam results indicated an overall improvement in students' post-test GPA (Grade Point Average) compared to their pre-test GPA, with varying degrees of improvement among individual students. Statistical analysis using the paired t-test confirmed a statistically significant mean difference in GPA, supporting the hypothesis that the Purifying indoor air polluted by excess CO_2 does have a positive effect on students' academic performance. The study concludes that the purification of indoor air polluted by excess CO_2 has a positive impact on students' academic performance. By reducing CO_2 concentration and improving indoor air quality, students' focus, activeness, and overall academic performance can be enhanced. The study highlights the significance of affordable and accessible ventilation solutions in creating healthier and more conducive learning environments.

Keywords: Indoor air quality, Carbon dioxide (CO_2), Academic performance, Automated ventilation system, IoT-based ventilation, Tertiary education, Sri Lanka, Respiratory health

INTRODUCTION

Background of the study

Clean air is essential for maintaining health and well-being. The World Health Organization (WHO) notes that breathing clean air reduces the risk of stroke, heart disease, lung cancer, and respiratory diseases. However, 99%

of the global population breathes contaminated air, making air pollution one of the most significant threats to human health. Indoor air pollution is associated with respiratory infections—particularly among children, the elderly, and women—as well as allergies and building dampness issues (Gautier & Charpin, 2017). Carbon dioxide (CO_2), which is approximately 1.67 times denser than air, tends to remain near the bottom of enclosed spaces (Kurtzman, 2010). A study by Tian et al. (2023) reported that indoor air quality declines significantly when CO_2 exceeds recommended levels and suggested incorporating CO_2 purification modules into existing air conditioning systems to maintain healthy concentrations. Ventilation is essential for reducing indoor contaminants to acceptable levels. Modern air conditioning systems can effectively filter indoor air; however, such solutions are often affordable only to high-income households. Middle- and low-income families face greater challenges in addressing ventilation and CO_2 buildup. While opening windows and doors can help, this is not always practical—particularly at night—due to issues such as mosquito infestations and outdoor dust from construction sites. Academic performance is closely linked to health and cognitive function. Students with higher academic achievement often gain better employment prospects, higher salaries, and greater self-confidence. Exam performance serves as an important indicator of educational program effectiveness. Consequently, researchers have sought to identify environmental and personal factors that influence academic outcomes. Kabirikopaei et al. (2021) demonstrated a strong association between indoor air quality factors—such as ventilation system type, ventilation rates, fine particle counts, and O_3 and CO concentrations—and student scores. Similarly, Gardin and Requia (2023), in a nationwide Brazilian study, found that air pollution exposure was associated with declines in student marks ranging from 0.13% to 5.39%. Preliminary observations at ATI Batticaloa suggested that some students with poor academic performance also experienced respiratory symptoms, possibly linked to poor indoor air quality and excessive CO_2 exposure. These observations align with prior findings that reduced activity levels and diminished concentration may result from prolonged exposure to polluted indoor air. Based on this evidence, the present study investigates the impact of inhaling indoor air polluted by excess CO_2 on students' academic performance at ATI Batticaloa and proposes an affordable ventilation solution suitable for middle- and low-income households.

"What is the effect of inhaling indoor air polluted by excess CO_2 on students' academic performance?"

Justification

In recent years, several studies have focused on excessive CO_2 levels and unhealthy symptoms, especially respiratory diseases such as sore throat, irritated nose/sinus, combined mucous membrane, tight chest, and wheezing. This research study evaluates the effect of inhaling indoor air polluted by excess CO_2 on students' academic performance. Multiple studies (Alsubaie, 2014; Hedrick et al., 2013; Seppänen & Fisk, 2004; Sundell et al., 2011; Taylor et al., 2016) have examined the relationship between respiratory disease, CO_2 concentration, and ventilation. In general, these examinations provide evidence that there is a concrete connection between ventilation and respiratory disease. A study (Stafford, 2015) was conducted to investigate the effect of indoor air quality (IAQ) in school buildings on students' standardized test scores and school attendance rates. Several studies have been carried out on high CO_2 levels and respiratory disorders in different countries. Furthermore, several studies have been focused on the relationship between indoor air quality and students' academic performance.

However, there is limited empirical evidence on the effect of inhaling CO_2-polluted indoor air on academic performance in the Sri Lankan tertiary education context. This gap in the literature is particularly relevant for institutions serving middle- and low-income communities, where poor ventilation is more prevalent.

This study addresses that gap by investigating the impact of excessive indoor CO_2 exposure on the academic performance of students at the Advanced Technological Institute (ATI), Batticaloa. It also aims to quantify the relationship between CO_2 concentration and academic outcomes and to evaluate the effectiveness of an Internet of Things (IoT)-based automated ventilation system in maintaining healthy indoor air quality. By doing so, the research offers practical, low-cost interventions that could be applied in similar low-resource educational settings.

Research Objectives

The main objective of this study is to "***examine the impact of inhaling indoor air polluted by excess CO_2 on***

the academic performance of students at the Advanced Technological Institute (ATI) Batticaloa.".

To accomplish the main objective, the specific objectives are identified as follows.

1. **To identify** the students who are affected by respiratory diseases among the students who possess poor academic performance.
2. **To Measure** the concentration of CO_2 in the bedrooms of selected students.
3. **To propose and implement** IOT (Internet Of Things) based Automated ventilation system to maintain their health properly.
4. **To evaluate** whether the students' academic performance has increased or not after integrating the proposed system.

REVIEW OF LITERATURE

Multiple studies (Guo et al., 2023; Doutreleau et al., 2017; Zhang et al., 2017; Bekö et al., 2010; Corradi & Mutti, 2005) have focused on excessive CO_2 levels and harmful symptoms, particularly respiratory illnesses. Guo et al. (2023) assessed the effects of indoor Negative air ions(NAIs) on college students' cognitive performance, including reasoning, short-term memory, concentration, verbal ability, and health when they are exposed to high levels of pure CO_2. Four distinct scenarios (NAIs+500 ppm CO_2, 500 ppm CO_2, NAIs+2500 ppm CO_2, and 2500 ppm CO_2) were presented to forty college students. A subjective questionnaire was used to examine acute health symptoms, and the participants' lung function, heart rate, and blood pressure were all measured at the same time. The findings show that adding NAIs can lessen the symptoms of pure CO_2-induced heart rate rise, nose irritation or dryness, skin irritation or dryness, and sensations of tiredness. So, this study clearly shows that a high pure CO_2 level causes unhealthy symptoms.

Zhang et al (2017) examined how exposure to bio effluents and carbon dioxide (CO_2) affects people. The reference condition was modified with chemically pure CO_2 to produce exposure conditions with CO_2 at 1000 ppm or 3000 ppm. The same 25 participants were subjected to each condition for 255 minutes. Measurements were made on subjective evaluations, physiological reactions, and mental performance. The results revealed that exposures to bio effluents with CO_2 at 3000 ppm reduced perceived air quality; increased the intensity of reported headache, fatigue, sleepiness, and difficulty in thinking clearly; and reduced the speed of addition, the response time in a redirection task, and the number of correct links made in the cue-utilization test compared to pure CO_2. Tsai et al. (2012) carried out a study in Taiwan to determine whether any association exists between sick building syndrome (SBS) and indoor carbon dioxide (CO_2) concentrations. 111 office workers were subjected to this study, and the results showed that workers exposed to indoor CO_2 levels greater than 800 ppm were likely to report more eye irritation or upper respiratory symptoms. A significant study (Shriram et al., 2019) found that sick building syndrome (SBS) symptoms and poor perceived air quality were both caused by ventilation rates of less than 10 L/sec per person. And they demonstrated that exposure to CO_2 concentrations greater than 1000 ppm resulted in reduced school attendance as well as more severe headaches, fatigue, and concentration problems. Ventilation is the only way to purify the polluted indoor air rather than using modern air-conditioner and specialized electrical equipment when we considering the economy of the people, Several studies (Alsubaie, 2014; Hedrick et al., 2013; Seppänen & Fisk, 2004; Sundell et al., 2011; Taylor et al., 2016) examined at the association between respiratory disease, CO_2 concentration, and ventilation. A study (Lee et al., 2014) examined the association between indoor air pollutant levels and residential environment in children with atopic dermatitis (AD) living in Seoul. One of the most prevalent allergic illnesses in children is atopic dermatitis (AD), a persistent, itchy, and inflammatory skin condition. Pet hair, house dust mites, pollen, and breathing contaminated air are the main causes of the condition. They included 150 AD patients from Seoul in the trial. A questionnaire was used to evaluate the living environment, and indoor air pollution levels were directly measured within the homes. From this study, they proved that CO and CO_2 play a major role in ways that cause Atopic Dermatitis in humans.

López et al. (2023) carried out the study on Indoor Air Pollutants (IAPs). They mentioned that CO_2 is the most common IAP among them and is commonly used as a metric of IAQ. Indoor CO_2 concentrations can be significantly higher than outdoors due to human metabolism and activities, and they suggested that direct air capture technology can purify indoor air by reducing the CO_2 concentration.

Tian et al., (2023) built a CO_2 purification module that can be incorporated with existing air conditioning systems to maintain the indoor CO_2 concentration at healthy levels and they proved that their CO_2 purification module can keep the indoor CO_2 level to be close to or even lower than outdoor levels with an initial CO_2 concentration of 1000 or 2000 ppm. Stafford (2015) carried out the study in Texas to examine the effect of school indoor air quality (IAQ) on academic outcomes. The results showed that the indoor air quality renovations have a significant effect on academic outcomes, with performance on standardized tests improving significantly while attendance is unresponsive. Rough calculations suggest that indoor air quality renovations may be more cost-effective than class size reductions to improve test scores.

A large-scale study (Kabirikopaei et al., 2021) examined the associations between indoor air quality factors and student performance in K-12 classrooms in the Midwestern US. Various IAQ parameters were assessed seasonally in 220 US classrooms from the academic years 2015 to 2017, excluding the summer. The findings revealed that classroom indoor air quality is significantly influenced by mechanical system types and sufficient ventilation rates, and that these parameters have a significant impact on student learning outcomes. In addition, they suggested that adequate ventilation rates and efficient filters help to dilute contaminants in classrooms and potentially improve the performance of the students.

A study (Haverinen-Shaughnessy et al., 2015) was conducted in a 70-school district in the Southwestern United States during two academic years in order to examine the associations between different indoor environmental quality (IEQ) indicators and students' performance. The temperature (T), relative humidity (RH), carbon dioxide (CO_2), and settled dust were all measured. Significant correlations were found between the percentage of students passing math and reading exams and both indoor temperature ($r = -.353$ and $r = -.311$ respectively) and ventilation rate ($r = .417$ and $r = .479$ respectively), which were measured using CO_2 levels. The results have shown that the rate and temperature of the classroom ventilation, as well as the cleanliness of the high-touch surfaces, seem to be significant IEQ variables that could potentially be related to students' health or academic performance. The findings support the generalization that surface cleaning, heating, ventilation, and air conditioning are the key operational measures for modifying the school environment to enhance students' health and academic performance.

According to the studies mentioned above, excess CO_2 is one of the main contaminants polluting indoor air, and indoor air can be purified by removing excess CO_2 using a CO_2 purification module that can be incorporated into existing ventilation systems. The above-mentioned studies (Stafford, 2015; Kabirikopaei et al., 2021; Haverinen-Shaughnessy et al., 2015) show the concrete association between indoor air quality and students' academic performance.

Thus, this study intended to focus on the application of the concepts in the Sri Lankan context, as there is limited research that has been conducted in this area of study in Sri Lanka as well as other developing countries.

METHODOLOGY

Research Design

This study adopted a quantitative panel design to evaluate changes in academic performance among students with previously poor results who also suffered from respiratory diseases. Statistical data were used to assess the impact of improved indoor air quality following the installation of an automated ventilation system in their bedrooms. Academic performance was measured both before and after the intervention.

Research Hypothesis

This present study focuses on the impact of indoor air polluted by excessive CO_2 levels on students' academic performance.

H_1 (Alternative Hypothesis):
Purifying indoor air polluted by excess CO_2 does have a positive effect on students' academic performance.

H_0 (Null Hypothesis):
Purifying indoor air polluted by excess CO_2 does not affect students' academic performance.

Structure of the Questionnaire

The questionnaire contained two sections:

1. **Personal information** – age, gender, number of family members, number of bedrooms.
2. **Research-related information** – number of occupants per bedroom, average sleeping duration, ventilation availability, and presence of pulmonary patients in the household.

Closed-ended questions were used to ensure efficiency and reliability when collecting responses from groups of students.

Study Population and Sampling

The study was conducted at the Advanced Technological Institute (ATI), Batticaloa. The target population comprised students with a Grade Point Average (GPA) below 2.0, as defined in the SLIATE Student Handbook (2017 onwards). Using secondary data from the Examination Department, 100 students were initially selected through simple random sampling. From this group, 30 students were chosen using stratified sampling based on the following criteria:

1. The student had a diagnosed pulmonary disease.
2. The student's family included more than three occupants sleeping in the same bedroom.
3. The bedroom had very little or no ventilation.

The final sample included 15 students from the Higher National Diploma in Information Technology (HNDIT), 7 from Higher National Diploma in English (HNDE), 6 from Higher National Diploma in Accountancy (HNDA), and 2 from Higher National Diploma in Tourism and Hospitality Management (HNDTHM).

Table 1. Distribution of Students with Low Academic Performance by Department and GPA

No	Student Name	Department	GPA
1	S1	HNDIT	0.78
2	S2	HNDIT	1.51
3	S3	HNDIT	0.83
4	S4	HNDIT	1.7
5	S5	HNDIT	0.82
6	S6	HNDIT	0.45
7	S7	HNDIT	0.41
8	S8	HNDIT	1.47
9	S9	HNDIT	0.99
10	S10	HNDIT	0.6

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11	S11	HNDIT	1.7
12	S12	HNDIT	1.17
13	S13	HNDIT	1.84
14	S14	HNDIT	1
15	S15	HNDIT	0.97
16	S16	HNDE	1.5
17	S17	HNDE	1.26
18	S18	HNDE	1.59
19	S19	HNDE	1.29
20	S20	HNDE	1.98
21	S21	HNDE	1.82
22	S22	HNDE	1.05
23	S23	HNDA	1.19
24	S24	HNDA	1.88
25	S25	HNDA	0.56
26	S26	HNDA	1.7
27	S27	HNDA	1.41
28	S28	HNDA	1.88
29	S29	HNDTHM	1.41
30	S30	HNDTHM	1.76

Then, data was gathered twice from 30 students selected for our study and evaluated for the recommended solution. The selected 30 students were informed in detail about our study and the benefits of the study to them. As well, an acceptance letter was given to each student to continue the study (because we needed to deploy our developed system in their bedrooms).

The selected 30 students' bedroom conditions needed to be studied, such as CO_2 concentration while they sleep, the ventilation rate in their bedrooms, the amount of CO_2 produced by their metabolic process, and the rate of change of CO_2 concentration with time. Sleeping time, the number of occupants who are sleeping in a bedroom, and ventilation details were recorded from earlier data collection via questionnaire. The CO_2 concentration and the rate of change of the CO_2 concentration with time are the only additional requirements. The CO_2 concentration reader was developed to collect those details, and it was deployed in the 30-bed rooms.

A study (Pirapuraj et al., 2021) examined the indoor CO_2 concentration, and they suggested an automated ventilation system for maintaining the indoor CO_2. They developed a CO_2 concentration reader using a Raspberry Pi, a CO_2 sensor, and a power supply. The Raspberry Pi had been selected to develop the CO_2 concentration reader rather than using Arduino, because when Arduino is used, getting a timestamp is difficult. The timestamp was needed to analyze how the CO_2 concentration is changing with time. It was easy to use the Raspberry Pi because the Raspberry Pi has an operating system (a Linux operating system) in it. Therefore, getting system time from the operating system is easy. And a Memory Chip (Memory SD Card) in it to store the record frequently. The same system was developed for this study.

RESULTS ANALYSIS AND DISCUSSION

Analysis of data collected from 30 students

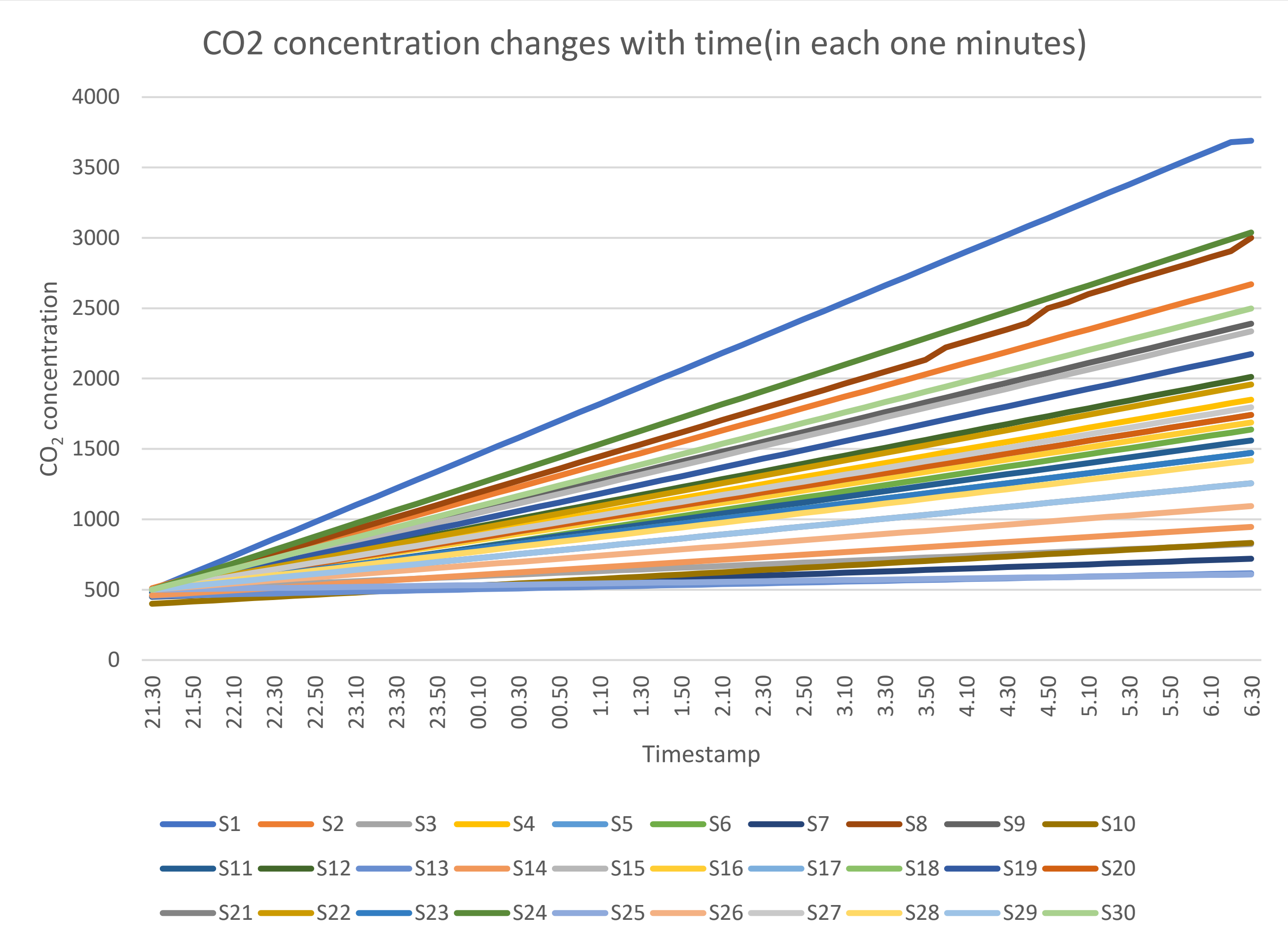

Figure 1: Full CO_2 concentration reading of the bedroom of 30 students (9:30:00 PM to 6:30:00PM) every 01 minute

As discussed in Section 5, the CO_2 concentration and its rate of change over time were measured in the bedrooms of selected students. Figure 1 illustrates how the CO_2 concentration changes over time in the bedrooms of 30 students. Measurements were taken between 9:30 PM and 6:30 AM. The indoor air quality in the bedrooms of students S1, S8, and S24 was in a highly critical condition, with CO_2 concentrations exceeding 3000 PPM. The bedrooms of other students, except for S3, S7, S10, S13, S14, and S25, were also in unhealthy conditions, with concentrations above 1000 PPM. Students S3, S7, S10, S13, S14, and S25 slept in healthy environments, inhaling fresh air with an average CO_2 level of about 500 PPM. They did not require any ventilation devices as their bedrooms already had good ventilation. Therefore, students S3, S10, S13, S14, and S25 were excluded from further research analysis.

The remaining 24 students were selected for the deployment of the developed system-an automated ventilation system.

Analysis of data collected using an automated ventilation system

Prapuraj et al. (2021) developed an automated ventilation system that maintains the indoor CO_2 concentration below 1000 PPM. They set the maximum CO_2 concentration value at 1000 PPM and the minimum CO_2 concentration value at 500 PPM in their developed system. The CO_2 sensor of the system monitors the CO_2 concentration inside the bedrooms. Once the maximum threshold value is reached, it reduces the CO_2 concentration by switching on the exhaust fan, and it will continue to work until the minimum threshold value is reached. Likewise, the CO_2 concentration inside the bedroom is maintained in a healthy range.

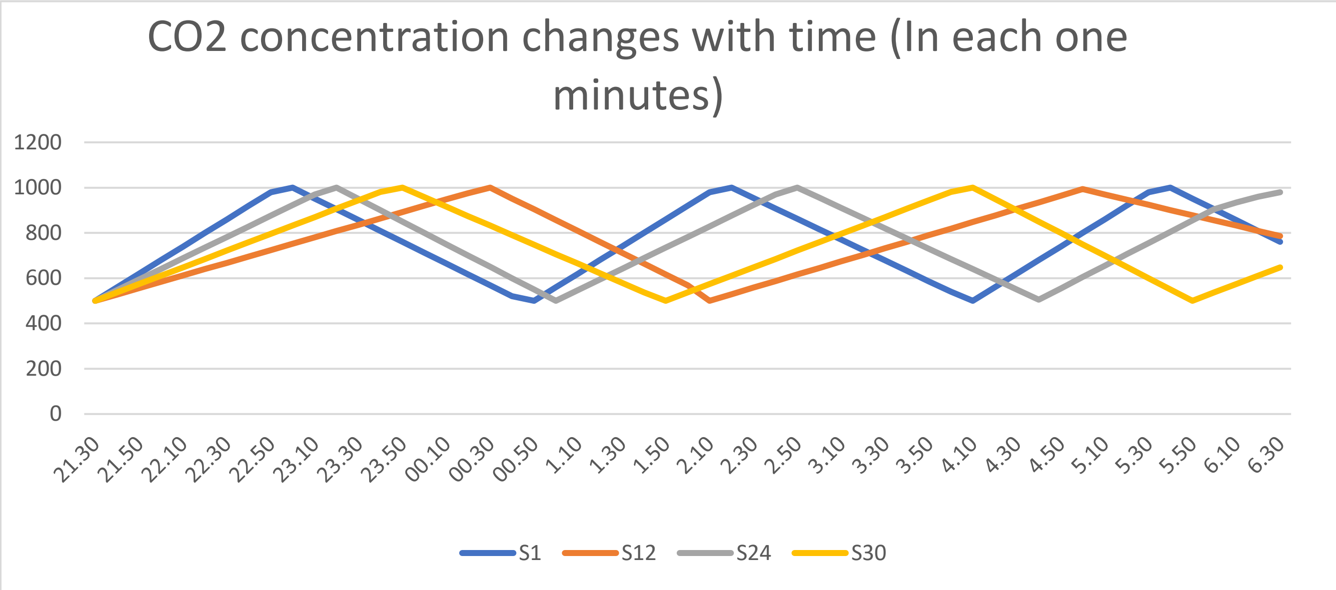

Figure 2. CO_2 concentration in bedrooms with automated ventilation, maintained between 500–1,000 ppm.

Initially, four students were selected to validate the system, and automatic ventilation was deployed in their bedrooms. Figure 2 describes how the CO_2 concentration changes over time in the bedrooms of selected students after the deployment of the automated ventilation system.

When we see Figure 2, the maximum CO_2 concentration value is 1000 PPM, and the minimum CO_2 concentration value is 500 PPM inside all the bedrooms of the four selected students. It means the CO_2 sensor monitors the CO_2 concentration inside the bedrooms; once the maximum threshold value is reached, it reduces the CO_2 concentration via the switch on the exhaust, and it will continue to work until the minimum threshold value is reached. Likewise, the CO_2 concentration inside the bedroom is maintained in a healthy range. So, the automated ventilation system maintains the indoor health condition perfectly. Finally, the developed system was deployed in the remaining 20 bedrooms of the students. The developed system was kept in all selected students' bedrooms for an entire semester. The examination results of the chosen research participants were considered for further studies.

Analysis of exam results after the deployment of the system

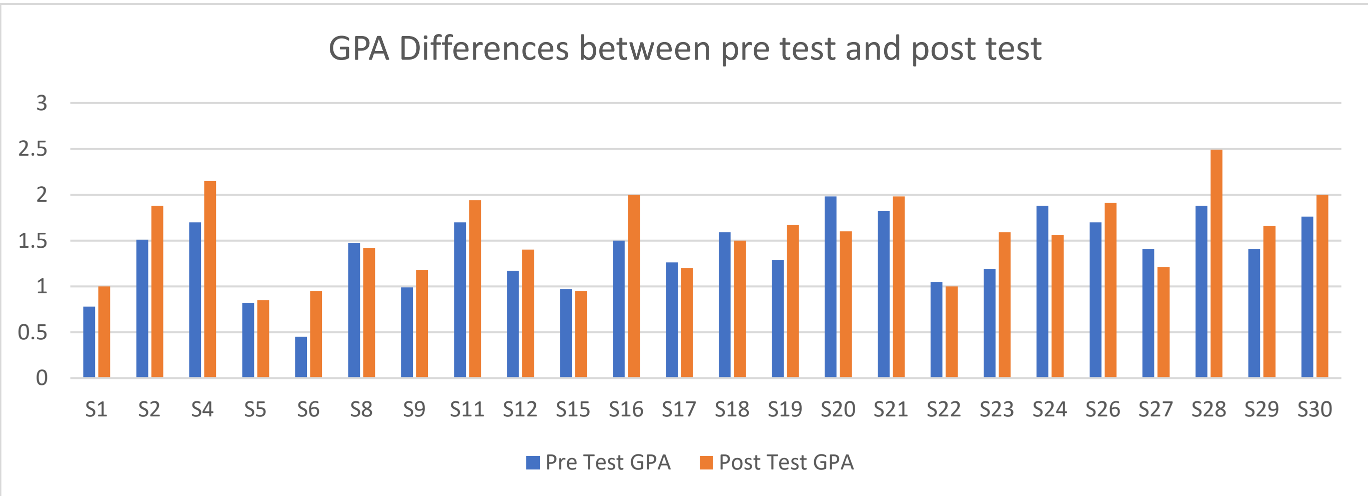

Figure 3. Pre-test and post-test GPA for 24 students after automated ventilation intervention.

Figure 3 describes the comparative analysis of the post-test GPA and pre-test GPA differences on student academic performance. Here are a few observations based on the above figure:

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Overall Improvement: A majority of the students demonstrated an increase in their post-test GPA compared to their pre-test GPA. This suggests an overall improvement in academic performance.

Varying Magnitude of Improvement: The extent of improvement varied among the students. Some students exhibited significant improvements, such as S4 (0.45 increase), S16 (0.50 increase), and S28 (0.61 increase). On the other hand, some students showed smaller improvements, like S1 (0.22 increase), S9 (0.19 increase), and S11 (0.24 increase).

Stable Performance: Several students maintained a relatively consistent GPA between the pre-test and post-test, with minimal differences. Examples include S5 (0.03 increase), S15 (-0.02 decrease), and S22 (-0.05 decrease).

Minor Declines: Few students experienced a slight decrease in their post-test GPA compared to their pre-test GPA. Notable examples are S8 (-0.05 decrease), S17 (-0.06 decrease), and S18 (-0.09 decrease).

The findings indicate that a substantial number of students experienced a positive GPA difference, suggesting academic progress and an improvement in their learning outcomes after the deployment of the automated ventilation system. Further statistical analysis was performed on the above findings to support the research hypothesis. Statistical verification of these differences was conducted using a paired-samples t-test in SPSS (Version 23), as reported in Tables 2 and 3.

Analysis of the statistical test

The paired t-test is used to compare the difference between two means of related samples. Related samples indicate measurements taken from the same subjects at two or more different times/situations. Table 2 shows Descriptive statistics for pre-test and post-test GPA scores of participating students.

Table 2. Descriptive statistics for pre-test and post-test GPA scores of participating students.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post Test GPA	1.5454	24	.44165	.09015
	Pre Test GPA	1.3867	24	.39890	.08142

Table 3. Paired samples t-test results comparing pre-test and post-test GPA scores.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post Test GPA - Pre Test GPA	.15875	.26381	.05385	.04735	.27015	2.948	23	.007

This research study investigated the impact of purifying indoor air polluted by excess CO_2 on students' academic performance. The paired sample test results revealed a statistically significant mean difference in GPA between the post-test and pre-test measurements. The findings suggest that purifying indoor air polluted by excess CO_2 positively affects students' academic performance.

The mean difference of 0.15875 indicates an average increase in GPA following the purification process. This suggests that improving indoor air quality through purification measures can contribute to enhanced academic outcomes for students. The 95% confidence interval (0.04735 to 0.27015) further supports these findings, indicating a high level of confidence that the true population mean difference falls within this range.

The statistical analysis, with a t-value of 2.948 and a corresponding p-value of 0.007, demonstrates the statistical significance of the observed mean difference. This indicates that the likelihood of obtaining such a significant difference by chance alone is relatively low. Consequently, the null hypothesis—that purifying indoor air polluted by excess CO_2 does not affect students' academic performance—can be rejected.

These results align with previous research highlighting the importance of indoor air quality in educational settings. For example, Stafford (2015) examined the effect of indoor air quality (IAQ) renovations in schools on academic outcomes and found that improvements in IAQ had a significant positive impact on standardized test scores, indicating that students' performance improves as a result of IAQ enhancements.

Similarly, Kabirikopaei et al. (2021) examined the associations between IAQ in K–12 classrooms and student academic performance. A multivariate linear regression analysis was conducted to investigate the relationships between IAQ factors and student scores while controlling for demographic variables. The results revealed significant associations between student scores and factors such as ventilation system type, ventilation rates (estimated from measured CO_2 concentrations), fine particle counts, and O_3 and CO concentrations. The findings highlight the importance of considering IAQ factors—such as ventilation rates and pollutant concentrations—in educational settings to create healthier and more conducive learning environments.

Haverinen-Shaughnessy et al. (2015) also assessed indoor environmental quality (IEQ) in schools and its association with health and performance. This study found significant relationships between IEQ indicators and student performance. Specifically, indoor temperature and ventilation rate were correlated with students' satisfactory scores in mathematics and reading tests.

High levels of CO_2 in indoor environments have been associated with adverse health effects and reduced cognitive performance. The current study provides further evidence supporting the positive impact of air purification measures in mitigating these effects and improving students' academic performance.

While the observed GPA improvements were associated with reduced indoor CO_2 levels, it is important to note that other factors may have contributed to the results. For example, students' socioeconomic background could influence access to better nutrition, healthcare, and study resources, which in turn affect academic outcomes. Environmental stressors such as noise pollution, humidity, or poor lighting may also impact concentration and performance. Additionally, differences in individual study habits, family support, and extracurricular commitments could have played a role. Although these confounding variables were not controlled for in the present study, acknowledging them is essential for interpreting the findings with appropriate caution. Future research should incorporate these variables into the study design to better isolate the specific effects of CO_2 reduction on academic performance.

CONCLUSION, RECOMMENDATIONS, AND LIMITATIONS

Conclusion

This research study investigated the impact of inhaling indoor air polluted by excess CO_2 on students' academic performance and explored the effectiveness of a purification system in improving indoor air quality. The findings of the study indicate that the purification of indoor air polluted by excess CO_2 has a positive effect on students' academic performance.

The analysis of exam results revealed an overall improvement in students' post-test GPAs compared to their pre-test GPAs. While the magnitude of improvement varied among students, a substantial number demonstrated positive GPA differences, indicating academic progress and enhanced learning outcomes. Statistical analysis using the paired t-test confirmed the significance of the observed mean difference, supporting the research hypothesis that purification measures positively influence students' academic performance.

These findings align with previous research studies highlighting the importance of indoor air quality in educational settings. Other studies have shown that improvements in indoor air quality have a significant positive impact on standardized test scores and student performance. Factors such as ventilation rates, pollutant concentrations, and IAQ indicators have been linked to students' academic achievements, emphasizing the need to consider IAQ factors in creating healthier and more conducive learning environments.

The current study contributes to the existing body of knowledge by providing evidence of the positive impact of air purification measures in mitigating the adverse effects of indoor air pollution on students' academic performance. By reducing excess CO_2 and improving indoor air quality, students' focus, activeness, and overall academic performance can be enhanced. This research highlights the importance of affordable and accessible ventilation solutions, particularly for middle-class and low-income families who may face challenges in dealing with indoor air pollution.

In conclusion, the implications of this study are significant, as they underscore the need for effective air purification systems to create a healthier and more conducive learning environment. By improving indoor air quality through the reduction of CO_2 pollution, educational institutions can enhance academic outcomes for students.

It is important to acknowledge potential limitations of the study, such as the specific context and sample characteristics. Further research is recommended to validate and generalize these findings across diverse educational settings and student populations. Additionally, exploring the underlying mechanisms driving the observed improvements in academic performance would provide valuable insights for future interventions and policies aimed at enhancing indoor air quality and optimizing learning environments.

RECOMMENDATIONS

Based on the conclusion of the research study, the following recommendations can be made:

1. **Implement Effective Air Purification Systems:** Educational institutions should prioritize the installation and maintenance of air purification systems to improve indoor air quality. These systems should specifically target the reduction of CO_2 pollution, as it has been shown to have a positive impact on students' academic performance. Regular monitoring and maintenance of these systems are essential to ensure their effectiveness.

2. **Raise Awareness and Provide Education:** Schools, teachers, and parents should be educated about the importance of indoor air quality and its impact on students' academic performance. Workshops, training sessions, and information campaigns can help raise awareness about the benefits of clean indoor air and the role of air purification systems. This knowledge can empower stakeholders to take necessary actions to create healthier learning environments.

3. **Consider Ventilation Solutions:** Along with air purification systems, effective ventilation solutions should be implemented in the bedrooms of students and educational settings. Adequate ventilation helps in maintaining good indoor air quality by promoting the circulation of fresh air and the removal of pollutants.

4. **Encourage Collaboration and Research:** Collaboration between educational institutions, researchers, and policymakers is essential to further investigate the relationship between indoor air quality and academic performance. Future research should focus on diverse educational settings and student populations to validate the findings and generalize the outcomes. Additionally, studying the underlying mechanisms and specific factors influencing the observed improvements in academic performance can guide the development of targeted interventions.

5. **Provide Support for Low-Income Families:** Special attention should be given to middle-class and low-income families who may face challenges in dealing with indoor air pollution. Affordable and accessible air purification systems, along with educational resources on maintaining good indoor air quality, should be made available to these families. Policies and initiatives should aim to reduce indoor air pollution disparities and ensure that all students have access to a healthy learning environment.

Limitations

While the research study provides valuable insights into the impact of indoor air pollution on academic performance and the effectiveness of ventilation solutions, it is important to consider its limitations. Here are some limitations of the research:

1. **Sample Size and Selection:** The study relies on a relatively small sample size of 30 students from a single institution. The generalizability of the findings to a larger population may be limited. The use of judgment sampling further restricts the representativeness of the sample.

2. **External Factors:** The research does not account for other potential factors that could influence academic performance, such as socioeconomic status, sleep quality, study habits, or other environmental factors outside of CO_2 levels. These factors may confound the relationship between indoor air quality and academic performance.

3. **Subjective Measurement:** The academic performance of the students is assessed based on GPA, which may not capture the complete picture of their abilities and achievements. Other objective measures or performance assessments could provide a more comprehensive evaluation.

4. **Lack of Long-term Follow-up:** The research study does not provide information on the long-term effects of improved indoor air quality on academic performance. It would be valuable to track the students' progress over an extended period to assess the sustainability of the intervention's impact.

5. **Potential confounding variables:** Socioeconomic status, noise levels, lighting conditions, and students' study habits were not measured or controlled for in this study. These factors may have contributed to changes in academic performance and should be considered in future research.

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