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THE SCIENTIST AS A HUMANIST

Hope M. Bandal, Ph. D.

Maxino College, Dumaguete City

In 1945, World War II ended with a big bang. Atomic bombs were dropped on Hiroshima and Nagasaki, killing in Nagasaki alone more than 40,000 people. This in a flash which only lasted seconds. The question which was on many people's minds then as it is now is: Was the destruction of Hiroshima and Nagasaki a creation of science – in particular physics? Or more fundamentally, has the practice of physics resulted to a decadence in and an erosion of human values?

To address these questions, it is essential that we look into the relationship between science and human values. A valuable insight could be obtained by recognizing the fact that while the findings of science are ethically neutral, the activity of science is not. The scientific activity is a continuous search for truth. For a person to succeed in this activity, he must possess certain qualities which grow naturally out of the habit for truth.

Since science embodies a commitment to explore the truth and since scientists are men who are fallible, then the values of science are inevitably human values. The scientific spirit has for its basis respect for the dignity of man. What then are the values of a scientist? Of a physicist?

Foremost among these is independence of observation and thought. One must learn to see, do, and think for himself, even in the face of those who seem to know everything. That is why, when experiments are performed, observations are recorded truthfully and accurately as they occur and not fitted to one's expectations of the results.

When Albert Einstein worked on his theory of relativity, he obtained results which seemed contrary to common sense. Time and length became relative concepts, dependent on the frame of reference of the observer. But the originality of the new concepts of space and time which Einstein introduced, came as a consequence of independence of thought and observation. Because Einstein's frame of mind was not bounded by traditional concepts

and even by common sense, he was able to liberate his ideas from the realms of the ordinary and to move into the world of very tiny particles and very high speeds. In such a world, strange things happen by common sense standards, such as the slowing down of clocks when objects move with speeds approaching the speed of light. Einstein's originality was a product of his independence of thought and observation. The same is true with the originality of a child's drawing which can sometimes startle us, just as Einstein's theory startled the physicists in his time. In a child as in a scientist, originality is a mark of independence of thought and observation. Originality is a badge of scientific activity.

But one cannot be original unless he learns to be a non-conformist. Independence of mind necessitates dissent from established ideas and beliefs, in the sense of constructive questioning and criticism. Galileo was a non-conformist when he questioned the geocentric theory and Aristotle's view on freely falling bodies. His questioning of these was but a natural consequence of the conviction that science should be a search for truth, not truth as a dogma as what Aristotle believed, but truth revealed in the continuous process of testing and experimentation. In his time, Aristotle was so well respected as a genius and a scientist that his views were not questioned for around 2000 years. But Galileo broke the mold and moved physics forward to another plane.

Dissent is the mark of a society which is growing. Take it out and a society stagnates and dies. The history of science is full of scientific dissenters. Copernicus was one of them and because he challenged the established contemporary world picture at that time which was that of the Earth being the center of the universe, he paved the way for Newton's Law of Universal Gravitation. He helped science grow as it has, a constant quest for truth.

But then dissent can flourish only in an atmosphere of freedom. If science is to be effective as a practice, there must be free inquiry, free thought, free speech, tolerance. In a repressive society, man cannot think freely and express his thoughts without fear of sanction. But ideas flourish in an atmosphere of freedom. One can meaningfully and effectively search for truth only if he is free to pursue and rectify ideas found to be erroneous.

Thus, the practice of science and physics in particular, leads to the development of the values of independence of thought, originality, dissent, freedom and tolerance. But why tolerance? Because science as an activity grafts and unites the work of one man with another. It is not an individualistic pursuit. Science cannot survive without acknowledgment and trust in the intrinsic dignity and worth of the works of different scientists and hence, the value and dignity of these scientists as persons. Tolerance, therefore, as a component of scientific activity, must be a tolerance based on respect for the other person and not on indifference.

Even when an experiment in physics is performed, for example, one wants to find out what kind of images is formed by different lenses, he is actually working by experimenting with the help of a series of lensmakers and scientists who discovered the laws of refraction and the behavior of light as it travels in different media. In other words, one has to rely on the works of physicists before him, on the knowledge and the store of data and information which has been built up communally.

Thus, science can be kept alive only by a constant balancing between independence from the views of others and tolerance for them, by constant tension between dissent and respect. This attitude of respect for other scientists had been aptly expressed by Isaac Newton when he said, "If I have seen farther than others, it has been by standing on the shoulders of giants." One of the giants Newton referred to was Galileo.

Science is also built on self-respect. And self-respect means being honest with one's self even when no one is watching. In an experiment, we record data as we get them not only because we might be changing the results of the experiment if we did not do so, thus making our conclusion unreliable. We record data as we get them because if we do not, we are teaching ourselves to be dishonest. And the work of science is of one piece, in the generalizations and in the details. If we are dishonest about our means even in one small detail, we infect ourselves and the results altogether. And our work loses its integrity because we have lost ours.

To paraphrase the mathematician and philosopher W. K. Clifford: If we steal money from a person, there may be no harm done from the mere transfer of possession. After all, the person may be rich and he may not feel the loss. We may be even preventing him from using the money badly. But we are doing a great wrong to society by making ourselves dishonest. The danger is not that society loses its property. The danger is that we would be making society a den of thieves for then it would cease to be an organized society.

So also in physics, we must practice our craft with dignity, not because we might make the wrong conclusions if we did not. After all the conclusions we make may not even matter. We must practice physics with dignity and honesty because if we do not, we would be infecting the very roots of physics and physics would cease to grow.

Finally, since science is a learning process by steps of which none is final, scientists must have the humility and the courage to correct their errors and to stand corrected. True humility – the acceptance of one's limitations as well as the recognition of one's capabilities is the mark of a scientist. Newton is made no less greater because of the formulation of Einstein's theory of relativity which revealed the limitations of Newtonian mechanics. Newton's mechanics was the foundation upon which Einstein built his relativistic mechanics. The work of one scientist is grafted onto the other, and no one nor his work is diminished by this act.

Science is often conceived to be bereft of values. But those who think so confuse the findings of science with the activity of science. While the findings of science are ethically neutral, the activity of science is not. The scientific activity is a deeply human undertaking, a constant quest for truth – an activity which is ingrained with independence of thought and observation, originality, freedom and dissent, tolerance and respect, humility and a deep regard for human dignity. These traits are borne out of the practice of science and are necessary for this practice.

Again, we go back to the question: Has science dehumanized our values?

The answer is no. The problem is not that human values cannot control a mechanical body of science. The dilemma is that the scientific spirit is more humane than most of the machineries of society. For society still thrives on self-interest and intolerance, thus breeding conflict. Society

has taken on the body of knowledge of science and left behind the scientific spirit of tolerance and respect for human dignity which should guide the technical knowledge. Massacre, as what happened in Hiroshima and Nagasaki, is not prevented by sticking to gunpowder and suppressing Einstein's $E=mc^2$ equation, the equation which unfolded the equivalence of mass and energy. Massacre is prevented by the scientist's ethic, the poet's ethic and every creator's ethic for that matter. It is prevented by a sense of respect for human dignity and a deep respect for God's creation.

There is a unity in the universe, a harmony in its natural laws. Science tries to find that unity, to unfold the principle that governs the abacus and the rose alike, the intellect and the heart.

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DETERMINATION OF CADMIUM IN LOWLAND RICE BY ATOMIC ABSORPTION SPECTROSCOPY

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ABSTRACT

Cadmium concentration in rice plant samples was determined using atomic absorption spectroscopy (AAS). The rice plant was separated into grains, husks, stalks, leaves, and roots. The samples were sundried to remove the moisture and heated in a furnace until they turned into white ash. The dry-ashed samples were then subjected to acid digestion using nitric acid and were subsequently filtered and diluted with deionized water before they were subjected to AAS analysis. Trace amounts of cadmium were found in all the samples. The highest cadmium concentration was found in the stalks and leaves, and the lowest was found in the grains.

INTRODUCTION

Heavy metals build up in soil through industrial activities such as mining, smelting, and refining metals and through agricultural practices such as applying organic manure, fertilizers, and pesticides [1]. Once heavy metals are present in the soil, plants absorb them through their roots, leading to accumulation in their leaves, stems, and fruits. Consuming food from such contaminated plants has detrimental effects on human health. One of the heavy metals found in contaminated soils is cadmium, which is highly toxic and poses significant health risks [2]. It can cause severe damage to the kidneys, liver, lungs, heart, and bones. It is classified as a human carcinogen, can adversely affect the reproductive system, and can cause immune system suppression [3]. Chronic cadmium exposure has also been linked to neurological effects such as cognitive decline, memory loss, and impaired motor function [4].

Rice is a staple food in the Philippines and an essential commodity that Filipinos consume daily. It is a central component of the Filipino diet, consumed in almost every meal, including breakfast, lunch, and dinner. This heavy reliance on rice as the main source of nutrition for the Filipino people makes it imperative to monitor and test rice for heavy metal contamination to ensure food safety. Studies have reported the presence of heavy metals, such as cadmium and lead, in Philippine rice [6,7,8].

In this study, cadmium concentration in rice samples obtained from a farm in Pangasinan was determined using atomic absorption spectroscopy (AAS).

METHODOLOGY

Sample Preparation

Rice plant samples were obtained from a farm in Pangasinan. The rice plants were separated into different parts: grains, husks, stalks, leaves, and roots. The samples were cut, placed in different crucibles, and left under the sun to dry for 5-6 hours to remove any remaining moisture. Once dried, the samples were heated in a ThermoLyne 48000 furnace for 17 hours at temperatures ranging from 600 °C to 650 °C until the sample turned white ash. The ashed samples were digested using nitric acid at standard room temperature for 24 hours and dried for 30 minutes. The powder obtained from the digestion was filtered and diluted with 100 ml of deionized water.

Atomic Absorption Spectroscopy

An AA-6300 Shimadzu atomic absorption spectrophotometer was used to determine the cadmium concentration in the prepared samples. Standard solutions of cadmium ranging from 100 ppb to 800 ppb were prepared for the calibration of the machine. The parameters for cadmium were inputted into the machine; the machine was then zeroed using 100 ml deionized water, followed by the calibration using the standard solutions.

RESULTS AND DISCUSSION

Figure 1 shows the calibration curve obtained using the standard cadmium solutions of concentrations ranging from 100 ppb to 800 ppb. It can be observed from the figure that there is a strong linear relationship between the absorbance and the cadmium concentration since the R^2 value is very close to 1. The equation obtained from the graph was used to calculate the cadmium concentrations in the real samples.

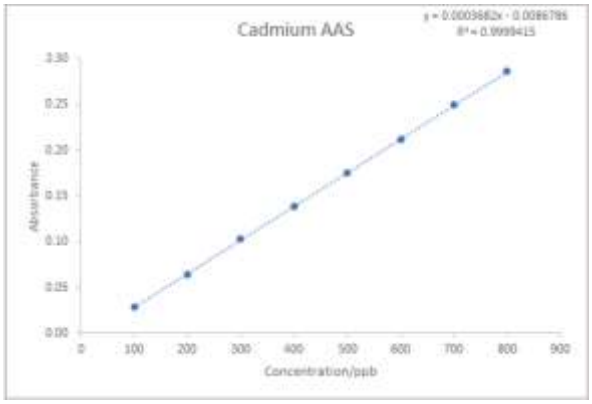

Figure 1. *AAS Calibration curve for Cadmium.*

According to Shaari et al., cadmium is readily absorbed by plants through their roots, and it is subsequently distributed equally throughout the plant [9]. The measured cadmium concentrations in the samples in this study are shown in Table 1 and Fig. 2. It can be observed that the cadmium content of the leaves, stalks, and husks is higher than that of the roots and grains. This elevated cadmium concentration in the exposed parts of the rice plant may be attributed to excess application of pesticides and atmospheric deposition from automobile exhaust, industrial emissions, and waste incineration [10]. The cadmium concentration in the rice

grains, 14.34 ppb, is way below the safety permissible limit of 200 ppb for rice grains according to the National Food Safety Standard of the People's Republic of China [8].

Table 1. *Cadmium concentration in the samples.*

	Cadmium			
	y = 0.0003682x – 0.0086786			
	y = absorbance		x = concentration	
Sample	y	m	b	**x (ppb)**
Husks	-0.0030	0.0003682	-0.00868	**15.42**
Grains	-0.0034	0.0003682	-0.00868	**14.34**
Leaves	-0.0027	0.0003682	-0.00868	**16.24**
Stalks	-0.0027	0.0003682	-0.00868	**16.24**
Roots	-0.0032	0.0003682	-0.00868	**14.88**

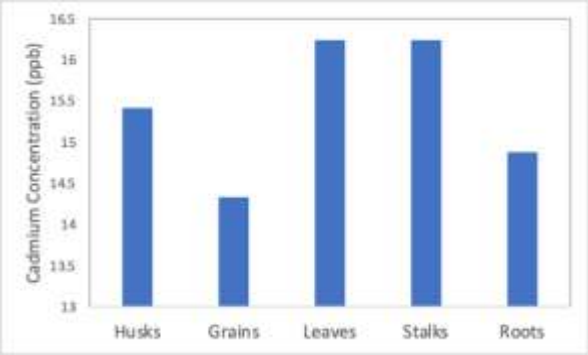

Figure 2. *Cadmium concentration in the samples.*

CONCLUSION

Trace amounts of cadmium were found in the rice plant samples. The highest cadmium concentration was found in the leaves and stalks of the rice plant. The rice grains contained the lowest amount of cadmium, which is below the safety permissible limit for rice grains according to the National Food Safety Standard of the People's Republic of China.

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ASSESSING $PM_{2.5}$ EXPOSURE AND RESPIRATORY HEALTH AMONG ELEMENTARY SCHOOL STUDENTS IN GUADALUPE, CEBU CITY

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ABSTRACT

This study explores the link between $PM_{2.5}$ levels and respiratory health among grades 4 to 6 students at Guadalupe Elementary School in Cebu City. $PM_{2.5}$ concentrations were measured inside classrooms and on nearby sidewalks, while surveys assessed respiratory symptoms and environmental factors. Classroom $PM_{2.5}$ levels were within safe limits, but sidewalk concentrations exceeded safe levels and correlated with symptoms like wheezing and coughing.

Keywords: *air pollution, ambient air quality, Cebu City, children, classrooms, elementary school, $PM_{2.5}$, respiratory health, indoor air quality, traffic emissions*

INTRODUCTION

Air pollution is an international health challenge worsened by rapid urbanization and increased vehicular emissions (Li et al, 2016; Tong et al, 2020; Madureira et al., 2015, Uy, 2024). Among the primary pollutants, particulate matter (PM), especially fine particles known as $PM_{2.5}$ with a diameter of 2.5 micrometers or smaller, has raised particular concern due to its increased risk of respiratory diseases for for both short and long-term exposure. (Mahiyuddin et al., 2023). Due to its minuscule size, $PM_{2.5}$ particles can penetrate deep into the lungs and even enter the bloodstream, posing various health risks, including respiratory diseases, such as allergies (Chun, et al., 2021; Undem & Taylor-Clark, 2014), asthma (Schleimer & Berdnikovs, 2017), respiratory infections (Yang, et al., 2020; Zareba, et al., 2024; Korppi, 2023), and chronic obstructive pulmonary disease or COPD (Li, et al., 2016; Zhao, et al., 2019; Sethi & Rochester, 2000; Wang & Liu, 2023; Mejza, et al., 2017; Do & Chin, 2011; Xu, et al., 2020). In severe cases, every 10 $\mu g/m^3$ increase in $PM_{2.5}$, it is associated with an approximated 6% increase in cardiopulmonary mortality and an 8% increase in lung cancer mortality (Pope et al., 2002). Globally, short-term exposure to $PM_{2.5}$ caused a 2.8% increase in PM-related

mortality, and a 1.6% increase in PM-related mortality for long-term exposure (Kloog, et al., 2013).

In highly urbanized areas like Metro Manila and Cebu City, $PM_{2.5}$ concentrations often exceed safe thresholds set by the World Health Organization (WHO) and the Department of Environment and Natural Resources (DENR) with levels up to ten times higher than in Europe or the USA (Alas et al., 2018). While recent improvements in air quality have been made, localized hotspots especially near schools remain a significant concern (Alas et al., 2018). Recent studies in Cebu City indicate average $PM_{2.5}$ concentrations at street intersections from pre-pandemic to post-pandemic decreased from 60 $\mu g/m^3$ to 12 $\mu g/m^3$ (Go et al., 2024) and air quality at skywalks in particular are generally below 35 $\mu g/m^3$ (Guadalquiver et al., 2024). Despite the noted improvement, localized hotspots particularly near schools and high-volume traffic areas remain a concern.

Children are especially more susceptible to $PM_{2.5}$ exposure due to their developing respiratory systems, higher breathing rates, and increased time spent outdoors and semi-enclosed areas such as classrooms near busy roads (Grigg, 2009; Che, Frey, & Lau, 2015; Rosalind & Brunst, 2013). Classroom factors such as ventilation quality and proximity to pollution sources, such as busy roads and chalk dust can further intensify $PM_{2.5}$ exposure levels (Guarnieri et al., 2014; Carrion-Matta et al., 2019; Villanueva et al, 2021).

Elementary schools are generally located in areas with high vehicular traffic, such as Guadalupe Elementary School in Cebu City (Hilapo & Salibay, 2021; Uy et al., 2024). Previous studies on $PM_{2.5}$ exposure on children's respiratory health linked increased risks to respiratory symptoms such as wheezing, chronic cough, frequent spitting and shortness of breath, reduced lung function, and elevated risks for asthma and other respiratory illnesses (Madureira et al., 2015; Chen et al, 2018; Bergstra at al., 2018).

This study looked into the relationship between $PM_{2.5}$ exposure and respiratory health outcomes among grades 4 to 6 students in Guadalupe Elementary School. By conducting surveys on respiratory symptoms and measuring $PM_{2.5}$ levels within classrooms and nearby sidewalks, this research provides some insights for improving air quality management in schools.

METHODOLOGY

Study Area and Participants

This study was conducted at Guadalupe Elementary School located along a road with high foot and vehicular traffic in Cebu City focusing on the Special Science Building, which accommodates grades 4 to 6 students. A total of 255 students from grades 4 to 6 participated, including 82 students from grade 4, 82 from grade 5, and 91 from grade 6. Students were selected based on the criteria of having been enrolled at the school for a minimum of two years ensuring they had sufficient exposure to the school environment. This minimizes the potential effects of short-term residency in the school or exposure to other environments on respiratory health outcomes.

Figure 1. *Special Science Building*

Figure 2. *Grade 6 Classroom*

Data Collection

$PM_{2.5}$ levels were measured using the AtmoTube Pro, a portable air quality sensor capable of monitoring real-time $PM_{2.5}$, $PM_{1.0}$, and PM_{10} concentrations as well as temperature and humidity data. Previous research using the AtmoTube Pro have demonstrated acceptable accuracy compared to standard reference instruments under both controlled and field conditions (Shittu, et al., 2024).

The device was hung on a tripod at an approximate height of 1.2 meters, which represents the breathing zone of the students, and the device was placed in the middle of the classrooms. Data collection took place from October to November 2024. Measurements were taken in classrooms once per week for five weeks during occupied conditions and over five consecutive days during unoccupied conditions in the afternoon. Each session lasted 10 minutes per classroom. Outdoor $PM_{2.5}$ levels were also measured on sidewalks adjacent to the school. Environmental factors, including temperature and humidity, were also recorded.

Survey for Respiratory Health Assessment

A survey was administered to all participating students, covering demographic information, respiratory health symptoms, family history, and potential exposure to indoor pollutants at home. Respiratory health questions were adapted from an established questionnaire by (Bergstra et al., 2018) and included items related to symptoms such as wheezing, frequent coughing, and difficulty breathing. The survey was translated into English and Bisaya, and pre-tested on a small group of non-participating students to ensuring understanding among students.

Statistical Analysis

The $PM_{2.5}$ data collected by the AtmoTube Pro were exported to a spreadsheet in CSV format and analyzed using Microsoft Excel 365 with Real Statistics Resource Pack add-in. One-way ANOVA was used to determine differences in $PM_{2.5}$ levels between indoor and outdoor environments and between occupied and empty classrooms. The level of statistical significance was set at $p \leq 0.05$ and a Tukey test was done in order to identify specific groups with significant differences.

To quantify $PM_{2.5}$ exposure and respiratory symptoms, a total exposure score was calculated from survey responses. Higher scores indicated greater exposure to air pollutants or more pronounced respiratory symptoms, allowing for correlation analysis between exposure and health outcomes.

RESULTS AND DISCUSSION

$PM_{2.5}$ Concentrations Inside Classrooms (Empty vs. Full/Occupied)

$PM_{2.5}$ concentrations were significantly higher in full/occupied classrooms with mean levels increasing from 7.5 µg/m³ in empty classrooms to 10.2 µg/m³ in full classrooms (Fig. 3). This increase is likely attributed to activities such as student movement and emissions from chalk dust or footwear debris. Despite the difference, all recorded levels remained within the "good" air quality range as defined by WHO and DENR standards.

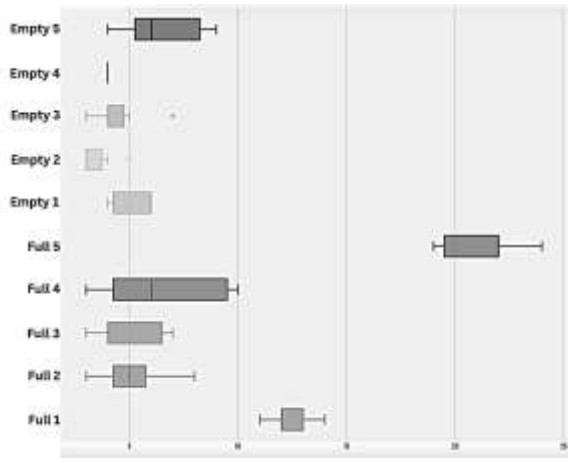

Figure 3. *$PM_{2.5}$ mean concentration between empty and full classroom trials.*

However, on the fifth visit where $PM_{2.5}$ levels ranged between 19-24 µg/m³, which could be attributed to the data being collected in the morning compared to other measurements taken in the afternoon. On the other hand, there is no significant difference in $PM_{2.5}$ mean concentrations between the classrooms, despite variations in ventilation quality and proximity to the main road.

These findings are similar with research conducted by Madureira et al. (2015) and Villanueva et al. (2021), which highlighted similar increases in $PM_{2.5}$ levels in occupied classrooms although for Guadalupe Elementary School, the air quality levels are considered good.

$PM_{2.5}$ Concentrations of Classrooms (empty, full) vs. Sidewalk

Outdoor $PM_{2.5}$ concentrations on sidewalks beside to the school ranged from 7 µg/m³ to 46 µg/m³ (Fig. 4), with a mean of 23.5 µg/m³ which is significantly higher than classroom levels ($p<0.05$). Sidewalk $PM_{2.5}$ levels were elevated which may be associated with vehicular emissions, particularly during afternoon rush hours where traffic density and idling vehicles were high. On days where rainfall was observed during data collection, rainfall helped lower outdoor $PM_{2.5}$ levels temporarily, consistent with findings by Girotti et al. (2025) on precipitation's role in particulate matter dispersion.

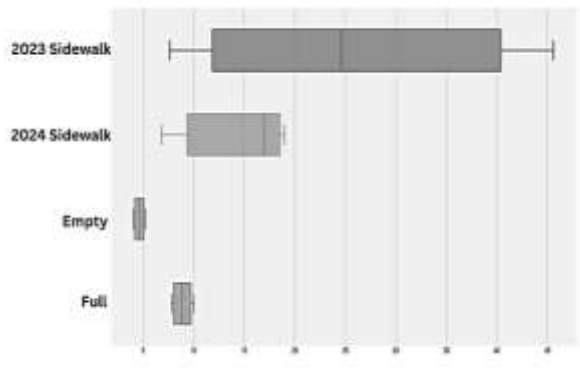

Figure 4. *$PM_{2.5}$ mean concentrations between empty classrooms, full classrooms, recent sidewalk data, and sidewalk data from 2023 and 2024.*

Using one-way ANOVA and Tukey Test on the $PM_{2.5}$ mean concentrations of full classrooms, empty classrooms, and sidewalk data from 2023 (Chong et al., 2024) and 2024 (Uy et al., 2024), significant differences were identified specifically $PM_{2.5}$ concentrations in empty classrooms were significantly lower compared to the 2023 sidewalk $PM_{2.5}$ data. However, no significant differences were observed between $PM_{2.5}$ levels in full/occupied classrooms and 2024 sidewalk data suggesting that classroom activity increases $PM_{2.5}$ levels to near outdoor concentrations.

These findings indicate that structural barriers such as school fencing and walls, and classroom distance from the street may reduce $PM_{2.5}$ concentrations towards the classrooms. But proximity to high traffic areas exposes students to elevated $PM_{2.5}$ levels during travel and outdoor activities stressing the importance of mitigating outdoor emissions near schools.

Temporal Variations in $PM_{2.5}$ Concentrations

Morning $PM_{2.5}$ concentrations were higher with a mean of 9.09 $\mu g/m^3 \pm 7.17$ $\mu g/m^3$ ($p<0.05$) compared to the afternoon mean of 7.18 $\mu g/m^3 \pm 5.74$ $\mu g/m^3$ (Fig. 5). Morning rush-hour traffic likely contributed to this trend. In contrast, higher wind speeds and humidity in the afternoon may have facilitated better particle dispersion, which lead to reduced $PM_{2.5}$ levels. This temporal pattern is similar to the study by Girotti et al. (2025) and Tong et al. (2020) where meteorological factors have an effect in moderating $PM_{2.5}$ concentrations.

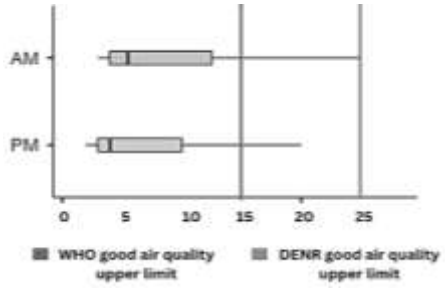

Figure 5*. $PM_{2.5}$ Mean concentration between morning and afternoon collections.*

Students' Respiratory Health and Associated Factors

Respiratory health among students was assessed using a questionnaire that inquired about symptoms such as wheezing, coughing, spitting colored sputum, shortness of breath, chest discomfort, and asthma. Responses were assigned 1 for "Yes" and 0 for "No." Based on the total score, students were categorized as **healthy** (0-2), having **minor respiratory issues** (3-4), or having **respiratory health issues** (more than 4).

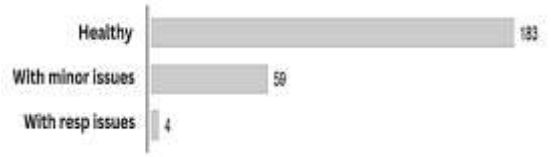

Figure 6. *Survey results of students' respiratory health.*

The results (Fig. 6) showed that 74.4% of students were categorized as healthy, 24.0% exhibited minor respiratory issues such as coughing and wheezing. Only 1.6% reported moderate health issues such as shortness of breath or frequent chest discomfort.

Age-wise (Fig. 5), students with respiratory issues were younger, with a mean age of 9.50 years ± 0.58, though the age difference was not statistically significant (p = 0.084).

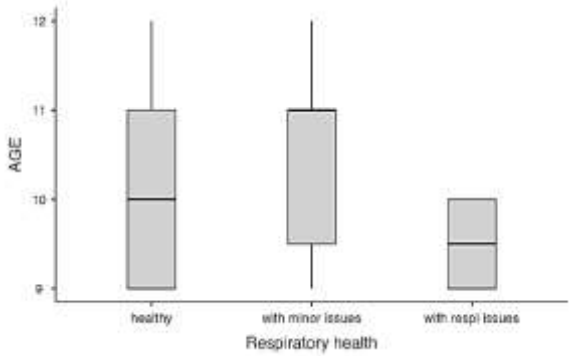

Figure 7. *Students respiratory health vs. age.*

The most common respiratory issue reported was frequent coughing, followed by shortness of breath and chest discomfort (Fig. 8).

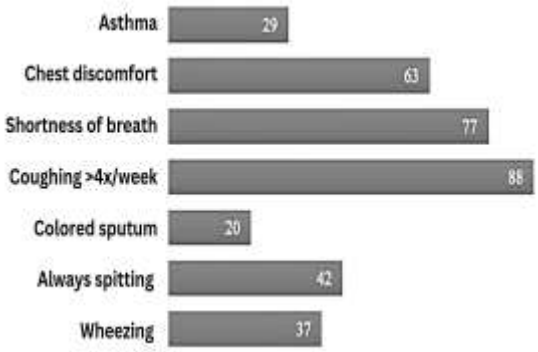

Figure 8. *Results of common respiratory symptoms gathered from the survey.*

Respiratory Illness in Relation to Home Environment and Comorbid Conditions

Among all the factors related to respiratory health, smoking within the household is significantly associated with children's respiratory health (p = 0.008). Exposure to environmental tobacco smoke (ETS) increases the risk of respiratory issues, such as wheezing. From the survey, out of 37 students who experienced wheezing, 25 students live with people who smoke, which means 67.6% of children who experienced wheezing lived with a smoker. This correlation is statistically significant, with X2(1)=6.59, p=.010.

Table 1. *Environmental Factors and Comorbid Conditions of Respiratory Health.*

Factors	Total Respondents $N = 246$	Healthy $n = 183$	w/ minor respiratory issues $n = 59$	w/ respiratory issues $n = 4$	p-value
Environmental factors					
Allergies to dust and animals	66 (26.9)	44 (24.2)	21 (35.6)	1 (25.0)	.228
Family member who smoke	118 (48.4)	77 (42.5)	38 (64.4)	3 (75.0)	.008
Use of firewood for cooking	20 (8.2)	15 (8.2)	4 (6.8)	1 (25.0)	.435
Presence of pets at home	159 (64.9)	114 (62.6)	43 (72.9)	2 (50.0)	.294
Presence of molds	62 (25.4)	42 (23.2)	19 (32.2)	1 (25.0)	.386
Smoking	4 (1.6)	2 (1.1)	2 (3.4)	-	.470
Rides jeepney daily	164 (67.2)	117 (64.6)	44 (74.6)	3 (75.0)	.349
Comorbid conditions					
Family history of asthma	77 (31.6)	58 (32.0)	17 (28.8)	2 (50.0)	.652
In-born lung disease	9 (3.7)	6 (3.3)	2 (3.4)	1 (25.0)	.074
Family history of lung disease	27 (11.1)	18 (9.9)	8 (13.6)	1 (25.0)	.498

Table 2*. One-way ANOVA of $PM_{2.5}$ in Full Classrooms and Sidewalk vs. Respiratory Health.*

One-Way ANOVA (Welch's)

	F	df1	df2	p
classroom pm2.5	0.197	2	8.12	0.825
sidewalk pm2.5	24.907	2	20.57	<.001

Group Descriptives

	Respiratory health	N	Mean	SD	SE
classroom pm2.5	healthy	183	4.32	1.38	0.102
	minor issues	59	4.24	1.25	0.163
	resp. issues	4	4.00	1.15	0.577
sidewalk pm2.5	healthy	148	18.16	11.52	0.947
	minor issues	45	19.80	14.22	2.120
	resp. issues	4	9.00	2.00	1.000

Respiratory Illness and Exposure to $PM_{2.5}$ in the Classroom and Sidewalk

While no significant relationship was found between classroom $PM_{2.5}$ levels and respiratory health ($p=0.83$), a strong correlation was observed between sidewalk $PM_{2.5}$ concentrations and respiratory health scores ($p < 0.001$). This discrepancy likely reflects the consistently low indoor $PM_{2.5}$ levels compared to often higher concentrations on the sidewalks.

The absence of significant health impacts from classroom $PM_{2.5}$ concentrations suggests that current ventilation in classrooms effectively mitigates indoor pollution. The strong relationship between sidewalk $PM_{2.5}$ levels and respiratory health highlights the importance of practical air quality interventions. Strategies like creating buffer zones, minimizing vehicles that idle near schools, and planting micro vegetation barriers may help lower students' exposure to outdoor air pollution.

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the relationship between $PM_{2.5}$ concentrations and respiratory health among students at Guadalupe Elementary School, Cebu City. Significant differences were observed between empty and occupied classrooms although $PM_{2.5}$ levels remained within WHO and DENR "good" air quality standards. Outdoor sidewalk $PM_{2.5}$ levels, however, frequently exceeded $PM_{2.5}$ safe air quality levels particularly during rush hours and were strongly associated with respiratory health symptoms such as wheezing and frequent coughing.

The findings emphasize the need for measures to address outdoor air pollution near schools, as well as other strategies to further minimize indoor $PM_{2.5}$ exposure. These measures are essential for protecting children particularly the vulnerable.

To reduce the increased high levels of $PM_{2.5}$ exposure on students, urban planning should prioritize micro buffer zones between schools and major roads. Traffic management strategies such as *no idling zones* around schools and better traffic flow during peak hours can help lower vehicular emissions. Schools can better improve air quality by installing air purifiers outside and inside classrooms as well as using greenery as natural pollution barriers. Community education on air pollution and involvement in monitoring activities can empower stakeholders to take action.

Future research may explore the long-term effects of $PM_{2.5}$ exposure on children's health and evaluate the effectiveness of proposed interventions should they be implemented. Expanding studies to include other schools in different urban areas may provide a broader understanding of air quality challenges.

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EVALUATING THE IMPACT OF PLAZA INDEPENDENCIA'S GREENSPACE ON $PM_{2.5}$ LEVELS IN CEBU CITY

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ABSTRACT

Urban greenspaces are known to help mitigate air pollution especially fine particulate matter ($PM_{2.5}$), which poses serious health risks in urban environments. This study investigated the impact of Plaza Independencia located in Cebu City, Philippines, on $PM_{2.5}$ concentrations. By use of monitoring points and zones, spatial and temporal variations in air quality were assessed to explore the role of greenspaces in reducing particulate matter. The study highlighted the potential of greenspaces to improve urban air quality. The findings provide insights for urban planning and emphasize the importance of enhancing greenspaces in densely populated cities.

Keywords: *air pollution, air quality, $PM_{2.5}$, particulate matter, greenspace, Plaza Independencia, Cebu City, urban areas, traffic, vegetation*

INTRODUCTION

The growth of cities like Cebu City, Philippines has brought significant challenges with declining air quality being one of the most pressing issues. Fine particulate matter (PM) especially $PM_{2.5}$, a pollutant 2.5 microns in diameter, which is enough to penetrate deep into the lungs and bloodstream, poses serious health risks including respiratory and cardiovascular diseases (de Castro et al., 2014; Espiritu & Lawas, 2019; Uy et al., 2024). Cebu City, recognized as one of the Philippines' most improved highly urbanized areas (CMCI, 2024), has seen its air quality decline due to increasing vehicle emissions and urban development such as the Bus Rapid Transit project (Go et al., 2024; Guadalquiver et al., 2024). This problem is similar to other studies' findings across Asia where exposure to outdoor air pollution has been linked to a surge in respiratory illnesses. A study from New Delhi reported a 24% increase in emergency room visits for conditions like Chronic Obstructive Airway Disease (COAD) and acute coronary events during periods of high air pollution (Chung et al., 2011; Pande et al., 2002).

$PM_{2.5}$ is concerning due to its ability to remain airborne for extended periods of time and penetrate deep into the respiratory system causing long-term health impacts where primary sources of $PM_{2.5}$ in urban areas

include vehicle exhaust, industrial activities, and biomass burning (CARB, n.d.; US-EPA, 2024). While larger particles like PM_{10} carry harmful substances such as heavy metals, $PM_{2.5}$ is more dangerous because it reaches further into the lungs. Although even smaller particles like PM_1 exist, $PM_{2.5}$ is widely monitored due to its prevalence and well-documented health risks (IQ Air, 2021). This study focuses on $PM_{2.5}$ because of its critical role in urban air pollution and its direct association with public health impacts.

Forecasting models further highlight the need of addressing high $PM_{2.5}$ exposure. Manatad and Sinogaya (2020) projected that as Cebu City's population and vehicular demands increase, PM levels will continue to rise with PM2.5 becoming an increasingly significant threat. Without intervention, emissions from the growing number of vehicles will likely push $PM_{2.5}$ concentrations beyond safe thresholds, exacerbating public health and air quality impacts/concerns. To address these risks, the Department of Environment and Natural Resources (DENR) has established a 24-hour safety limit for $PM_{2.5}$ at 35 $\mu g/m^3$ (DENR, 2023).

Urban greenspaces offer a practical solution for reducing $PM_{2.5}$ pollution. Vegetation reduces particulate matter through mechanisms like deposition, dispersion, and pollutant capture (Diener & Mudu, 2021). Research in Beijing, China, using the i-Tree Eco model, demonstrated that tree-dense greenspaces retain far more $PM_{2.5}$ than areas dominated by shrubs or grasses, with trees capturing up to 70,000 grams of particulate matter compared to 21,000 grams for shrub and grass-dominated areas (Yin et al., 2022). In Cebu City, Plaza Independencia, a historic urban greenspace with over 20,000 plants (Flores et al., 2020), presents a case study for examining how vegetation can influence air quality. The plaza's greenery has potential to filter airborne particulate matter and act as a natural barrier against pollution from nearby traffic.

This study evaluates the role of Plaza Independencia's greenspace in reducing $PM_{2.5}$ concentrations. By analyzing air quality data collected from various locations within and around the plaza, this research highlighted the environmental and public health benefits of urban vegetation. Additionally, the study examined the relationship between vegetation coverage and $PM_{2.5}$ levels, identifying plant species and coverage that may contribute to air purification. These findings aim to assist urban planning efforts and show the importance of preserving greenspaces in rapidly developing cities like Cebu City.

METHODOLOGY

Survey Area and Site Description

This study was conducted in Plaza Independencia, a historic greenspace in Cebu City, Philippines, located near the iconic Fort San Pedro. The plaza is not only a significant urban greenspace but also a popular destination for tourists and locals used as both a recreational area and a cultural landmark (Espina et al., 2017). Sixteen monitoring points were selected to capture variations in $PM_{2.5}$ concentrations grouped into four distinct zones based on their proximity to the plaza. **Zone 1** included points located at the center of the plaza consisted of points 1 to 4. **Zone 2** comprised points along its edges consisted of points 5 through 8, located along the edges of the plaza. **Zone 3** covered included points 9 to 12, covered 40 meters outside the plaza, and **Zone 4** consisted of points 13 to 16 extended to intersections around 100 meters from the plaza. Each zone

contained four points to ensure balanced data representation across all areas of interest and these zones were chosen to determine the gradient of $PM_{2.5}$ concentrations as they transitioned from the greenspace to urbanized areas influenced by vehicle emissions and other pollution sources nearby.

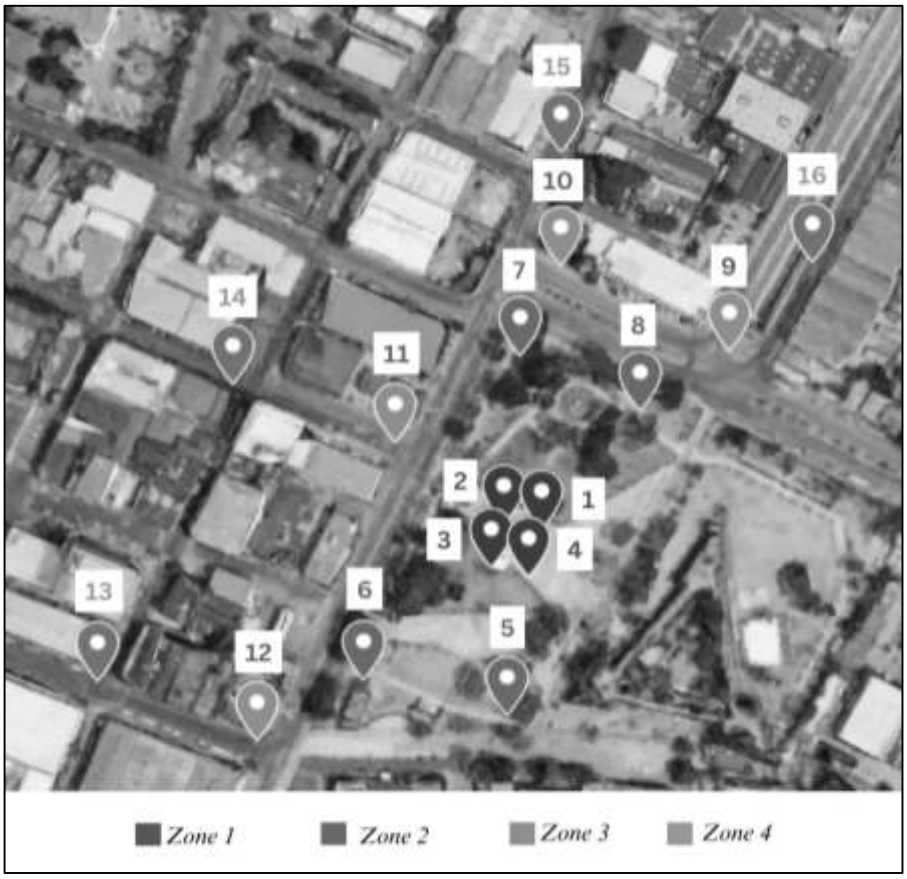

Figure 1. *Map of Plaza Independencia.*

Collection and Determination of $PM_{2.5}$ Concentrations

Data collection took place from October to December 2024 on Tuesdays and Saturdays, between 1:00 p.m. and 4:00 p.m. during a period with Cebu City's truck ban to minimize interference from heavy duty vehicles. $PM_{2.5}$ concentrations were measured using a handheld Atmotube Pro sensor (Shittu et al., 2024), which was held at chest height around 1.5 meters above ground near human breathing zones. Each monitoring point was sampled ten times, resulting in a total of five weekday and five weekend observations per point. Alongside $PM_{2.5}$ measurements, environmental conditions such as traffic density, vehicle types, and foot traffic were recorded to provide additional context. Photographs of vegetation were analyzed using the PlantNet application for species

identification, supplemented by consultations with park administrators to ensure accuracy.

Data Processing and Statistical Analysis

Data gathered by the Atmotube Pro were stored in its application and exported as .csv files for analysis in Microsoft Excel. Spatial differences in $PM_{2.5}$ concentrations between zones, a one-way Analysis of Variance (ANOVA) was performed where the ANOVA indicated a significant overall difference, a Tukey's HSD (Honest Significant Difference) test was conducted to identify the specific zones where these differences in $PM_{2.5}$ concentrations occurred. A significance level of $p<0.05$ was used for the statistical tests. Additionally, Pearson's Correlation Coefficient (r) was employed to evaluate the relationship between humidity, temperature, and $PM_{2.5}$ concentrations.

RESULTS AND DISCUSSION

$PM_{2.5}$ Concentration Trends Across Visits

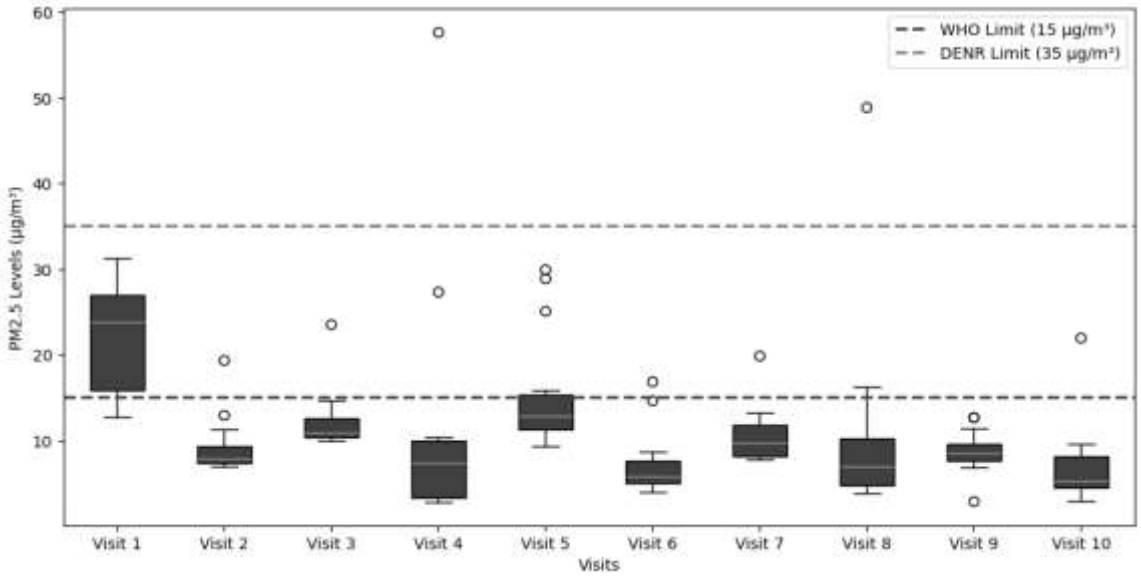

Figure 2. *$PM_{2.5}$ mean concentration in µg/m³ between visits from October to December*.

The statistical analysis showed significant variations in $PM_{2.5}$ concentrations across the monitoring points over the study period. Figure 2 shows Visit 1 $PM_{2.5}$ levels' peaking at 22.2 µg/m³, exceeding the World Health Organization's (WHO) recommended threshold of 15 µg/m³, although still within the Philippines' "Good" air quality classification below 35 µg/m³ (DENR, 2023). This elevated concentration coincided with an influx of tourist vehicles including police cars, which likely contributed to increased emissions. The

figure also shows Visit 1 not only having the highest median value but also indicates high variability as indicated by its wider interquartile range (IQR). These features suggest irregular pollution events tied to heightened activity levels.

In contrast, the lowest recorded concentration, 6.8 μg/m³, occurred during Visit 10, which coincided with reduced traffic activity and favorable weather conditions. The tight clustering of data points during Visit 10 indicates consistent and stable air quality during this time supporting the impact of decreased vehicular emissions. These temporal patterns emphasize the influence of both human activity and meteorological factors on air quality.

Subsequent visits showed lower mean $PM_{2.5}$ concentrations with notable differences observed in Visit 6 of concentration 7.1 μg/m³. This drop coincided with strong winds brought by Typhoon Kristine, which dispersed particulate matter and significantly changed air quality. Visit 6 shows a smaller range of $PM_{2.5}$ values with very few outliers highlighting how weather conditions such as strong winds effectively dispersed particulate matter and improved air quality. Visit 5, on the other hand, displayed relatively high $PM_{2.5}$ levels at 15.4 μg/m³ concentrations influenced by increased human activity within the plaza including the setup of tents, movement of vehicles, and a rise in foot traffic. The relative broader range of $PM_{2.5}$ levels seen for Visit 5 indicates fluctuations in pollution sources during this period.

The lowest concentration was recorded during Visit 10 (6.8 μg/m³) likely because of reduced traffic activity due to a rescheduling of sampling times to an early afternoon period (1:00–2:00 PM). The lack of extreme outliers for Visit 10 reinforces this observation, which showed consistent air quality conditions during this time. These results highlight the relationship between human activity, weather conditions, and time of day affecting $PM_{2.5}$ concentrations over time.

$PM_{2.5}$ Spatial Variations

a. Point-Level Analysis

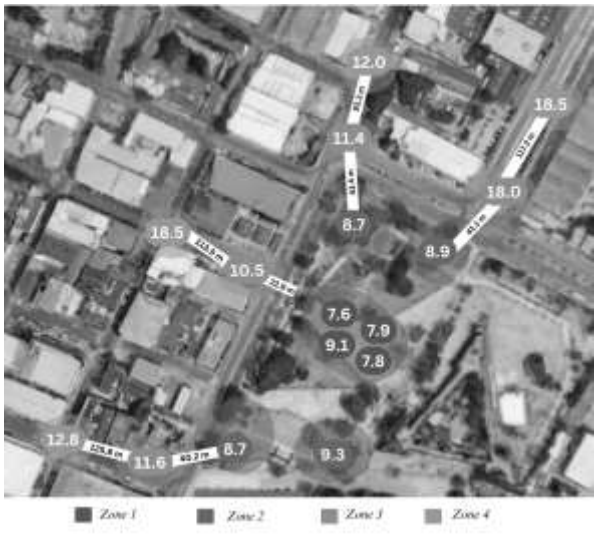

***Figure 3A**. Map of $PM_{2.5}$ mean concentration between points.*

Points located at the plaza center (Points 1 to 4) showed levels ranging from 7 μg/m³ to 9 μg/m³. These levels were significantly lower ($p = 0.025$) than the other points farther from the center of the plaza.

In contrast, Zone 4 (Points 13 to 16) recorded the highest concentrations ranging between 12 μg/m³ and 18.5 μg/m³ with Points 14 and 16 as outliers These elevated $PM_{2.5}$ levels were likely influenced by nearby construction and emissions from poorly maintained vehicles including trucks and

jeepneys. The broad IQR observed for Zone 4 indicates variability in pollution levels, which is likely influenced by periodic changes in vehicle traffic and ongoing construction activities in the area.

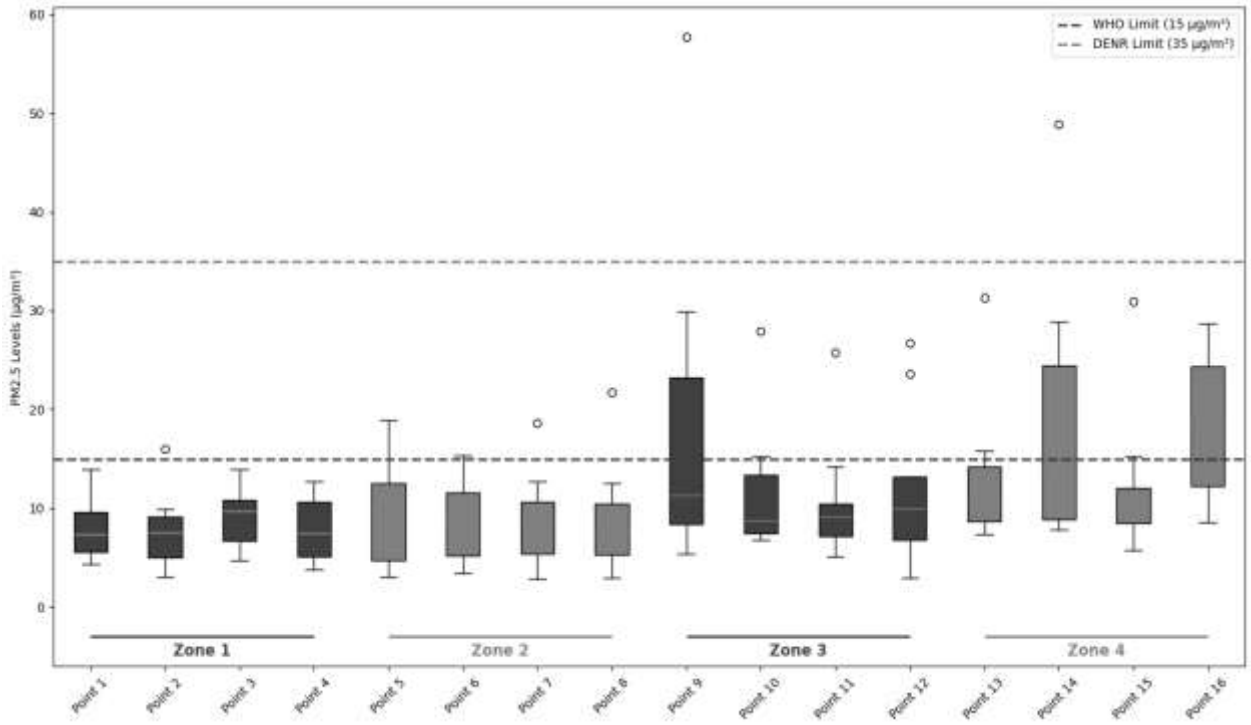

***Figure 3B**. $PM_{2.5}$ mean concentration between points.*

Zone 3 (Points 9 to 12) displayed moderate $PM_{2.5}$ levels 6 µg/m³ to 14 µg/m³) with notable outliers at Points 9 and 11. These irregularities may be due to the movement of large vehicles through intersections on the highway. Zone 2 (Points 5 to 8) displayed narrower IQRs indicating relatively stable air quality. However, the presence of some outliers suggests periodic changes potentially caused by increased foot traffic and vehicle emission sources.

b. Zone Level Analysis

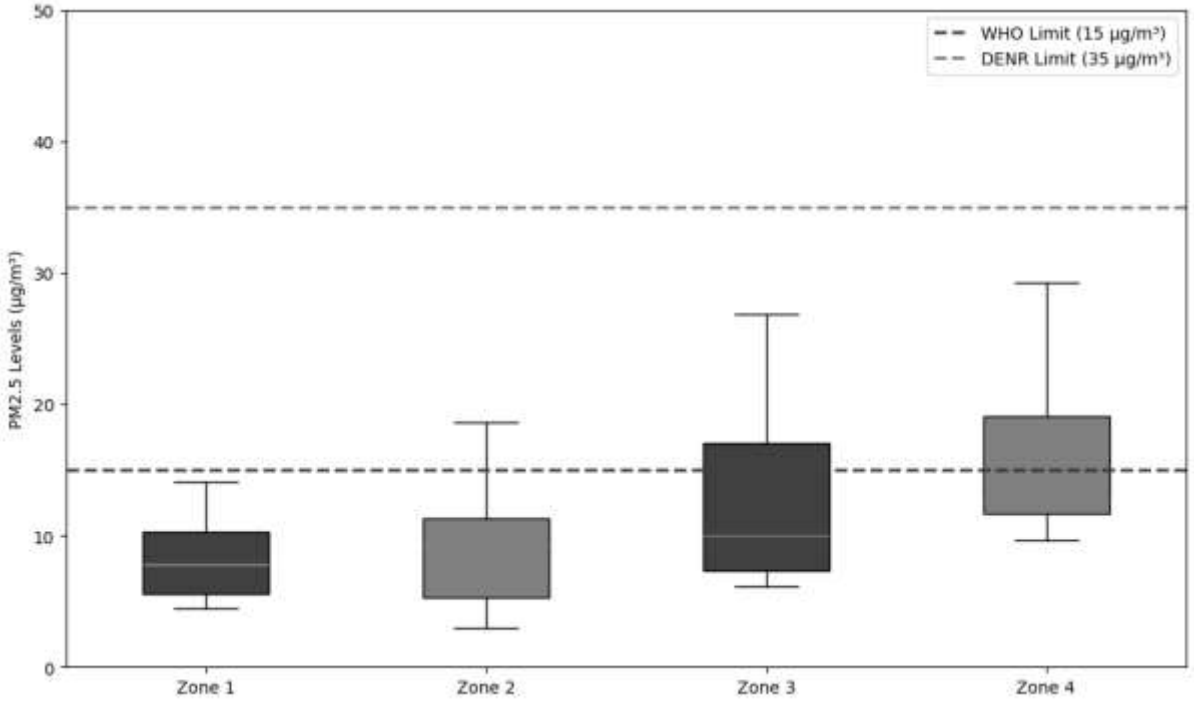

Figure 4. *$PM_{2.5}$ mean concentration between zones.*

$PM_{2.5}$ concentrations displayed a noticeable gradient across zones increasing with distance from the plaza center. Zone 1, located at the center of the plaza, recorded the lowest average concentration of 8.1 µg/m³ with a relatively narrow IQR indicating relatively stable air quality. Along the plaza's edges at Zone 2, concentrations remained relatively similar, with only a slight increase of 0.8 µg/m³. This small increase can be attributed to localized human activities.

At 40 meters from the plaza, Zone 3's $PM_{2.5}$ concentrations rose by 37.2% reaching an average of 12.9 µg/m³. The wider IQR in this zone suggests greater variability likely due to the influence of both plaza-related activities and vehicular emissions. The highest $PM_{2.5}$ levels were observed in Zone 4, 100 meters away, where concentrations averaged 15.8 µg/m³, a 47.4% increase compared to Zone 1. Data also showed a wider IQR in this zone indicating fluctuating pollution levels influenced by vehicular density, construction activity, and the distance away from the greenspace.

These spatial patterns suggest that while Plaza Independencia's greenspace significantly reduces particulate matter within its immediate vicinity, its effectiveness diminishes with distance. The outermost zones are more directly influenced by the distance of vehicular emissions and other urban activities stressing the limits of greenspaces in limiting pollution beyond their immediate boundaries.

Environmental Factors

Influence of Humidity and Temperature to $PM_{2.5}$ Concentrations

Analysis of environmental variables revealed weak correlations between $PM_{2.5}$ concentrations and both humidity and temperature. Humidity showed a slight positive correlation (r=0.16), while temperature exhibited a weak negative correlation (r=-0.13). These results indicate that while weather conditions can influence particulate dispersion, their role in this study was minimal compared to the effects of human activity and greenspace.

Vegetation Analysis

Vegetation Coverage

Figure 5A

Plaza Independencia consists of approximately 66% greenspace and 34% cemented areas as determined through spatial analysis. Figure 5 and 5A shows the aerial top view of the plaza while Figure 5B illustrates the distribution of vegetation and cemented areas. This distribution provides an opportunity for air quality improvements but also emphasizes the potential limitations in cemented aeras. For example, the cemented areas likely reduce the overall effectiveness of particulate matter filtration particularly in Zones 3 and 4, where higher $PM_{2.5}$ concentrations were recorded.

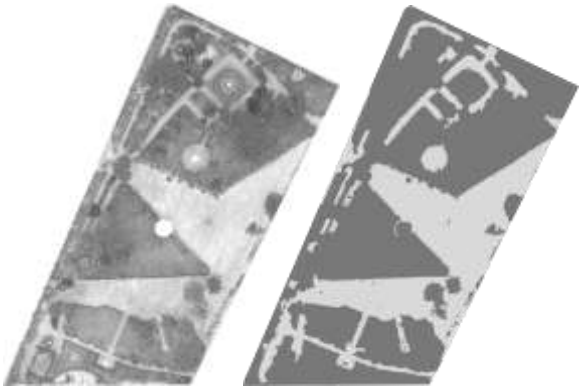

Figure 5B ***Figure 5C***

The significant presence of greenspaces in Plaza Independencia likely plays a key role in its ability to filter particulate matter and enhance air quality. Figure 4 illustrates $PM_{2.5}$ levels were lowest in Zone 1 located at the plaza's center where the density and proximity of greenspace are at the highest. In contrast, greenspace coverage diminishes in Zones 3 and 4 as the distance from Zone 1 increases exposing these areas to vehicular emissions from nearby roads. Enhancing vegetation in the outer zones could help offset the effects of pollutants coming from outside the plaza. However, nearby facilities such as the museum, seaport, and heritage sites, draw human activity, vehicle traffic, and parking, which presents challenges that may compromise air quality.

CONCLUSIONS AND RECOMMENDATIONS

This study showed the role that greenspaces like Plaza Independencia play in mitigating $PM_{2.5}$ concentrations within urban environments. The spatial analysis revealed that $PM_{2.5}$ levels were significantly lower within the plaza compared to the urban surroundings which emphasizes the capacity of vegetation to filter particulate matter and improve air quality. However, the plaza's ability to mitigate $PM_{2.5}$ diminishes with increasing distance, as concentrations rise in areas 40 to 100 meters beyond the greenspace. This indicates that while greenspaces provide localized benefits such as improved air quality, its influence is limited by external factors such as vehicular emissions and urban activities.

The study also found that environmental variables such as humidity and temperature had minimal impact on $PM_{2.5}$ levels highlighting the dominant role of human activities and vegetation in shaping air quality. With 66% of Plaza Independencia's area dedicated to greenery, the findings emphasize the value of preserving and enhancing greenspaces as a solution to urban air pollution.

It is recommended that future research explore additional factors influencing $PM_{2.5}$ concentrations such as wind direction, traffic volume, and specific characteristics of vegetation to better understand the complex interplay between greenspaces and urban air quality. Future studies may help identify strategies for integrating greenspaces into urban planning to promote healthier and more sustainable cities.

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AIR QUALITY IN A CHURCH IN CEBU CITY: $PM_{2.5}$, CO_2, AND THE INFLUENCE OF OUTDOOR POLLUTION SOURCES AND VENTILATION

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Bethany Christian School[1], University of San Carlos[2]

ABSTRACT

This study investigated $PM_{2.5}$ and CO_2 concentrations in a Cebu City church to assess air quality during service and non-service times both indoor and outdoors. Using a portable air quality sensor, results indicate $PM_{2.5}$ levels generally exceeded the WHO 24-hour guideline value of 15 µg/m³ but remained within the DENR's 35 µg/m³ threshold. Outdoor $PM_{2.5}$ levels were often higher than indoor levels influenced by vehicular emissions, industrial activity, and local burning of leaves. CO_2 concentrations remained within acceptable limits demonstrating effectiveness of natural ventilation in maintaining air quality especially in the church.

Keywords: *air quality, $PM_{2.5}$, CO_2, catholic church, service times, non-service time, indoor-outdoor air exchange, incense burning, ventilation*

INTRODUCTION

Urban air pollution is a global issue significantly contributing to respiratory diseases, cardiovascular conditions, and weakened immune responses (Cohen & Pope, 1995; Forsberg et al., 1993; Hansel et al., 2015). Fine particulate matter, specifically $PM_{2.5}$, which is characterized by particles with diameters of 2.5 microns or less, is considered harmful due to its ability to penetrate the pulmonary alveoli and enter the bloodstream causing systemic health effects (Anggraeni & Lestari, 2023; Garcia et al., 2023). To mitigate these risks, air quality guidelines set by the World Health Organization (WHO) recommend a 24-hour $PM_{2.5}$ threshold of 15 µg/m³, whereas the Philippines' Department of Environment and Natural Resources (DENR) has a more leeway where unhealthy levels start at 35 µg/m³ (DENR, 2020; WHO, 2021).

Cebu City, one of the Philippines' larger cities, frequently faces air pollution challenges (Saavedra, 2019) due to vehicular emissions, construction activities (Payus et al., 2017), and high population density (Iqbal et al., 2020; Tefera et al., 2021). Recent events, such as the 2024 eruption of Mt. Kanlaon, briefly elevated $PM_{2.5}$ levels capping at around 35 µg/m³ in Cebu (Palaubsanon, 2024). While within the DENR's threshold, the $PM_{2.5}$ concentrations still exceeded WHO's air quality guideline signifying the pressing need for effective monitoring and mitigation measures (Dela Peña, 2023; Go et al., 2024; Pasia et al., 2020; Pena, 2023). During peak vehicular activity, $PM_{2.5}$

concentrations have been reported to reach as high as 50 µg/m³, highlighting the health risks posed to Cebu's residents (Uy et al., 2024).

While several studies have investigated outdoor air quality, indoor air quality is equally important due to prolonged exposure to indoor pollutants, which may originate from both indoor and outdoor sources (WHO, 2010). Studies indicate that indoor $PM_{2.5}$ levels can surpass outdoor levels increasing the risk of respiratory issues in vulnerable populations (Ramachandran et al., 2003; Seguel et al., 2016). Factors such as limited ventilation, human occupancy, and specific activities like incense burning influence $PM_{2.5}$ concentrations indoors (Polednik & Polednik, 2016; Pagels et al., 2019). Additionally, CO_2 concentration serves as a key indicator of ventilation efficiency, human occupancy, and combustion activity with high levels of both CO_2 and $PM_{2.5}$ negatively impacting human comfort (Hussain et al., 2021; Wu et al., 2021).

Catholic churches, which serve as central community spaces in the Philippines, experience high occupancy during religious services making them important sites for assessing indoor air quality. However, limited research has examined variations in $PM_{2.5}$ and CO_2 concentrations during service and non-service times in Philippine churches.

This study focused on the Archdiocesan Shrine of Our Lady of Guadalupe de Cebu, examining $PM_{2.5}$ and CO_2 concentrations indoors and outdoors during service and non-service times. By analyzing spatiotemporal variations and environmental influences on pollutant levels, this research investigated how $PM_{2.5}$ and CO_2 concentrations in community spaces changes over time across different areas within the church space.

METHODOLOGY

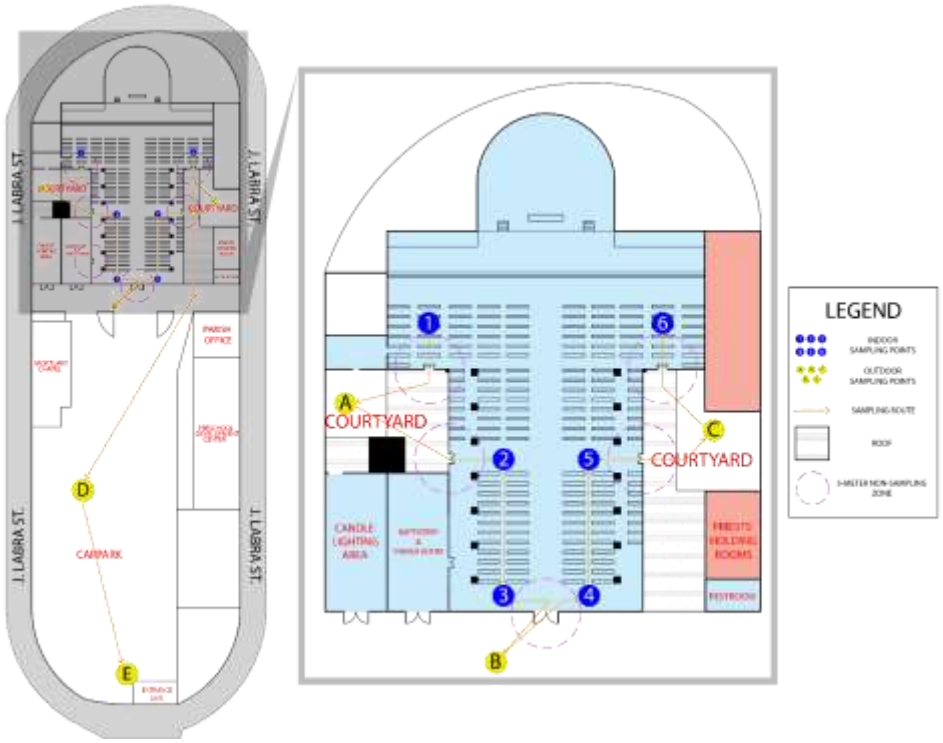

Figure 1. *Indoor and Outdoor Sampling Spots of the Archdiocesan Shrine of Our Lady of Guadalupe de Cebu.*

Study Site

This study was conducted at the Archdiocesan Shrine of Our Lady of Guadalupe de Cebu located in Barangay Guadalupe, Cebu City. The church serves as a representative site for urban Catholic churches in the Philippines characterized by its high ceilings, semi-open design, and proximity to major roads such as V. Rama Avenue and J. Labra Street. These roads are frequently used by both public and private vehicles contributing to elevated ambient levels of particulate matter. Sampling points were strategically selected to collect data in air quality within the church and its surrounding environment.

Research Instruments and Data Collection

$PM_{2.5}$ concentrations were measured using the AtmoTube Pro, a tested portable air quality sensor (Shittu et al., 2024). This device recorded real-time $PM_{2.5}$ levels at two-second intervals while also able to monitor humidity, temperature, and volatile organic compounds (VOCs). CO_2 levels were measured using the PASCO PASPORT Carbon Dioxide Sensor PS-2110 with readings taken every second. Data from both devices were logged and averaged over one-minute intervals to ensure accuracy and consistency.

Sampling Procedure

Sampling was conducted over three months, covering both service and non-service times. Service time measurements were taken during Sunday afternoon Masses from 4:00 p.m. to 5:30 p.m., when church attendance is typically at its peak (Dixon & Bond, 2004). Non-service times were sampled on weekday afternoons from 4:00 p.m. to 5:30 p.m., which is a time characterized by minimal human occupancy.

Indoor sampling included six points across the main seating area positioned at least five meters away from building openings. Outdoor sampling included five points near the church's entrances and parking areas as indicated in Figure 1. Each point was monitored for six minutes per session with ten sessions conducted during service times and ten during non-service times. Temperature, relative humidity, and any relevant activities were also recorded during each session to contextualize fluctuations in $PM_{2.5}$ concentrations.

Data Analysis

The collected data was exported to Microsoft Excel for analysis, with data on $PM_{2.5}$ and CO_2 concentrations treated using statistical software. One-way Analysis of Variance (ANOVA) was conducted to identify significant differences in pollutant levels between sampling periods, and a Tukey test was employed to determine specific factors contributing to these differences. The significance was set at p=0.05.

Indoor-to-outdoor (I/O) ratios were calculated to assess the impact of outdoor air on indoor pollutant concentrations. The I/O ratio was determined by dividing the indoor concentration (C_{in}) by the outdoor concentration (C_{out}) (Stamp et al., 2022).

$$\text{I/O} = \frac{C_{in}}{C_{out}} \qquad \text{Eq. 1}$$

RESULTS AND DISCUSSION

$PM_{2.5}$ Levels Across Service and Non-service Times for Indoor and Outdoor Locations

Figure 3.1.1 shows $PM_{2.5}$ concentrations inside and outside the church variations across service and non-service periods. However, no significant differences were observed between service and non-service times indoors ($p>0.05$), whereas a statistically significant difference was noted between indoor and outdoor concentrations ($p=0.023$).

The mean $PM_{2.5}$ concentration recorded during service times was 17.4 µg/m³, while the non-service period showed a slightly higher mean of 19.9 µg/m³. Despite the fluctuations across visits, statistical tests confirmed that service and non-service times did not significantly differ ($p=0.318$) although conditions such as incense burning, maintenance activities, and vehicular movement affected the variation between visits ($p<0.05$).

Indoor $PM_{2.5}$ levels were lower than outdoor levels with a mean indoor concentration of 16.4 µg/m³ compared to 20.7 µg/m³ outdoors. The one-way ANOVA confirmed that this difference was statistically significant ($p=0.023$). This suggests that despite the church's semi-open structure, the indoor environment would benefit from some level of air filtration or reduced sources of $PM_{2.5}$ compared to the external surroundings.

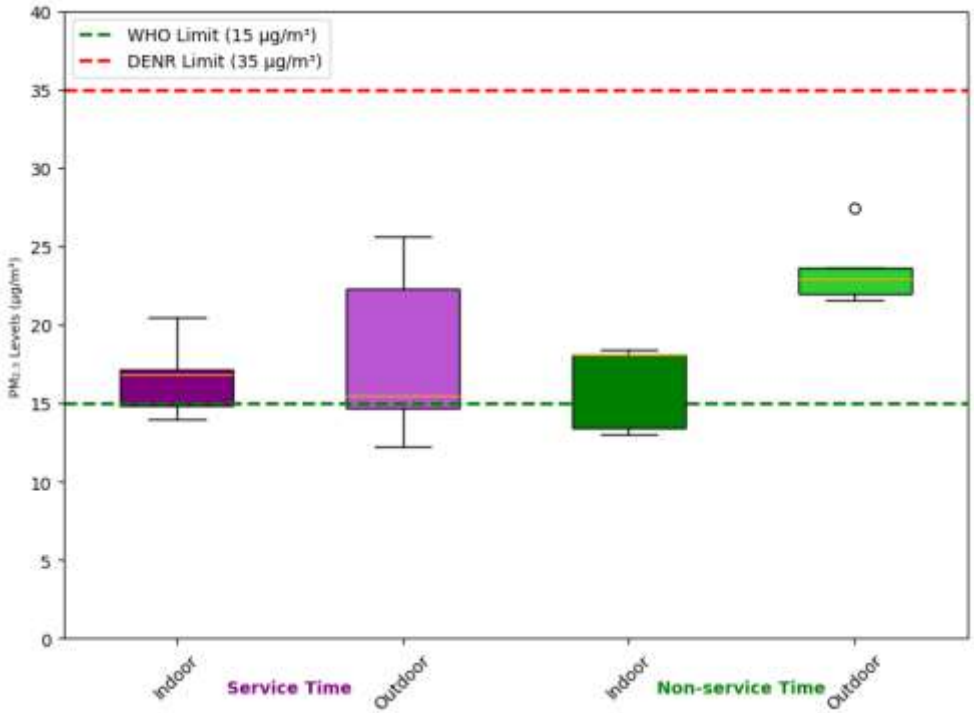

Figure 3.1.1 *Differences in $PM_{2.5}$ Concentrations Between Indoor and Outdoor and Between Service and Non-service Times.*

Significant differences in $PM_{2.5}$ concentrations were also found between specific locations within the church (p=0.0483) likely due to variations in architectural layout and airflow. The highest $PM_{2.5}$ concentration was recorded in a semi-enclosed indoor nook possibly due to limited air circulation in the area. This nook is located on the upper right side of the church, where it showed higher $PM_{2.5}$ levels than some of the outdoor spots due to its positioning relative to wind direction.

Right-side indoor locations exhibited similar $PM_{2.5}$ levels to outdoor areas indicating a strong airflow influence. In contrast, left-side indoor locations experienced lower $PM_{2.5}$ levels likely due to less exposure to the incoming wind. However, no significant differences were found between service and non-service times at these locations (p=0.381) suggesting consistent outdoor vehicular activity, likely from jeepneys, played a large role in $PM_{2.5}$ exposure throughout the day.

Indoor $PM_{2.5}$ levels averaged 16.6 μg/m³ during service times and 16.2 μg/m³ during non-service times exceeding the WHO-recommended 24-hour limit of 15 μg/m³ but remaining within the DENR safety threshold of 35 μg/m³ (WHO, 2021; DENR, 2020). The similarity between service and non-service times suggests that indoor activities such as incense burning, candle lighting, and cleaning (e.g., sweeping and floor polishing) produced comparable $PM_{2.5}$ levels.

Table 3.1.1. *Tukey-test Results Between Indoor and Outdoor Spots During Service and Non-service Times.*

	Group 1	Group 2	Mean (μg/m³)	p-value
1	Service Times (Indoor)	Non-service Times (Indoor)	0.44	0.997269325
2	Service Times (Indoor)	Service Times (Outdoor)	1.42	0.921313189
3	Service Times (Indoor)	Non-service Times (Outdoor)	6.86	0.035553927
4	Non-service Times (Indoor)	Service Times (Outdoor)	1.86	0.842567273
5	Non-service Times (Indoor)	Non-service Times (Outdoor)	7.3	0.024209491
6	Service Times (Outdoor)	Non-service Times (Outdoor)	5.44	0.115503449

Outdoor $PM_{2.5}$ levels were higher during non-service times (23.5 μg/m³) than during service times (18.1 μg/m³) but remained within the DENR safe standard. However, statistical analysis (Table 3.1.1, row 6) revealed that this difference was not significant likely due to the consistent vehicular emissions surrounding the church particularly from jeepneys that idle near the church while picking up and dropping off passengers.

$PM_{2.5}$ conditions were relatively the same inside and outside during service times (Table 3.1.1 row 2) likely due to effective ventilation in the church caused by three

factors: first, there was a large influx of people coming in and out of the church during service times which could have facilitated the mixing of indoor air with outdoor air. Second, electric fans (4 to the left and 5 to the right side of the church) which were located above the church's grill doors (see Figure 3.1.3), were also turned on and could have further aided in the ventilation of $PM_{2.5}$ in the church due to increased outdoor air infiltration resulting from the positioning of the fan (see Figure 3.1.2). Third, the main door of the church was kept open throughout the whole duration when services were conducted, which would have increased the potential for indoor and outdoor interaction especially in the regions closest to it.

During non-service times, indoor $PM_{2.5}$ conditions are similar to those outside during service times (Table 3.1.1 row 4). The absence of food vendors, church maintenance (which involved painting and sanding), and emissions from the nearby glass factory during service times may have reduced the amount of $PM_{2.5}$ produced outside the church, bringing it down to levels comparable to those experienced when there is less candle lighting done inside the church and no incense burning.

However, during non-service times, the indoor and outdoor conditions differed ($p=0.0242$, Table 3.1.1 row 5). Likewise, there was a difference between the outdoor conditions during non-service times and the indoor conditions during service times ($p=0.0356$, Table 3.1.1 row 3). The industrial emissions from a nearby glass factory, the repair activities (such as sanding and repainting the church courtyard walls), the burning of leaves and waste from the nearby residential area, and the cooking emissions from outdoor food stalls were probably the main causes of the significantly higher outdoor conditions during non-service times compared to the indoor conditions during both service and non-service times. Particular increases in outdoor $PM_{2.5}$ levels during non-service periods were frequently observed during sanding repair and grilling cooking activities.

Figure 3.1.2. *Electric fans are located above the grill doors on the right side of the church.*

Figure 3.1.3. *Grill-doors on the right side of the church.*

CO_2 Levels Across Service and Non-service Times for Indoor and Outdoor Locations

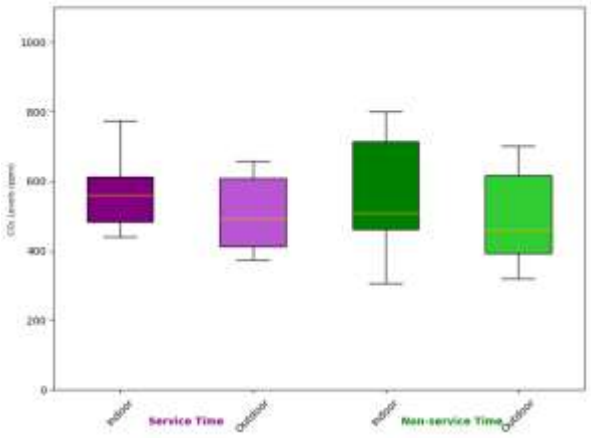

Figure 3.2.1 *Differences in CO_2 Concentrations Between Indoor and Outdoor and Between Service and Non-service Times.*

Figure 3.2.1 presents the differences between indoor and outdoor & between service and non-service times. There were no significant differences in CO_2 concentrations between service and non-service times for both indoor and outdoor environments ($p=0.599$). Although it would be expected that CO_2 levels would be higher during services due to increased human occupancy, the presence of the church's grill doors allowed CO_2 to disperse freely possibly avoiding any noticeable differences in $PM_{2.5}$ and CO_2 levels between service and non-service times.

No significant differences were found between indoor and outdoor CO_2 concentrations ($p=0.169$), again likely due to the open-air design of the church facilitated by the grill doors. Additionally, the constant presence of jeepneys and motorcycles in the vicinity may have contributed to background CO_2 levels during both service and non-service times as these vehicles continue to emit CO_2 through the combustion of diesel and gasoline regardless of whether a service is being conducted.

Although CO_2 levels varied significantly across different visits during both service and non-service times ($p<0.05$), the difference between these two periods remained statistically insignificant ($p=0.600$). Variability across visits could be attributed to fluctuations in human attendance and activities within the church. For instance, some services experienced greater congregation sizes, leading to higher CO_2 levels compared to others. Additionally, during certain non-service visits, the burning of leaves in nearby residential areas may have led to increased CO_2 concentrations, contributing to variability even during non-service periods.

Comparing Mean Indoor and Outdoor $PM_{2.5}$ and CO_2 Concentrations

The overall mean indoor $PM_{2.5}$ level independent of service or non-service times is visually shown in Figure 3.3.1. Figure 3.3.2 shows the indoor mean $PM_{2.5}$ concentration to be 16.4 µg/m³, while the mean outdoor $PM_{2.5}$ level is 20.8 µg/m³. While both values exceeded the WHO threshold of 15.0 µg/m³, they remained within the DENR's 35.0 µg/m³ 24-hour guideline.

Outdoor $PM_{2.5}$ concentrations were significantly higher than indoor concentrations ($p=0.023$) likely due to the persistent presence of vehicles such as jeepneys from the nearby stop, parked and idling cars within the church premises. In comparison, indoor sources of $PM_{2.5}$ such as incense burning, floor polishing, sweeping, and candle lighting were temporary and of shorter duration resulting in less substantial

indoor $PM_{2.5}$ accumulation compared to outdoor sources.

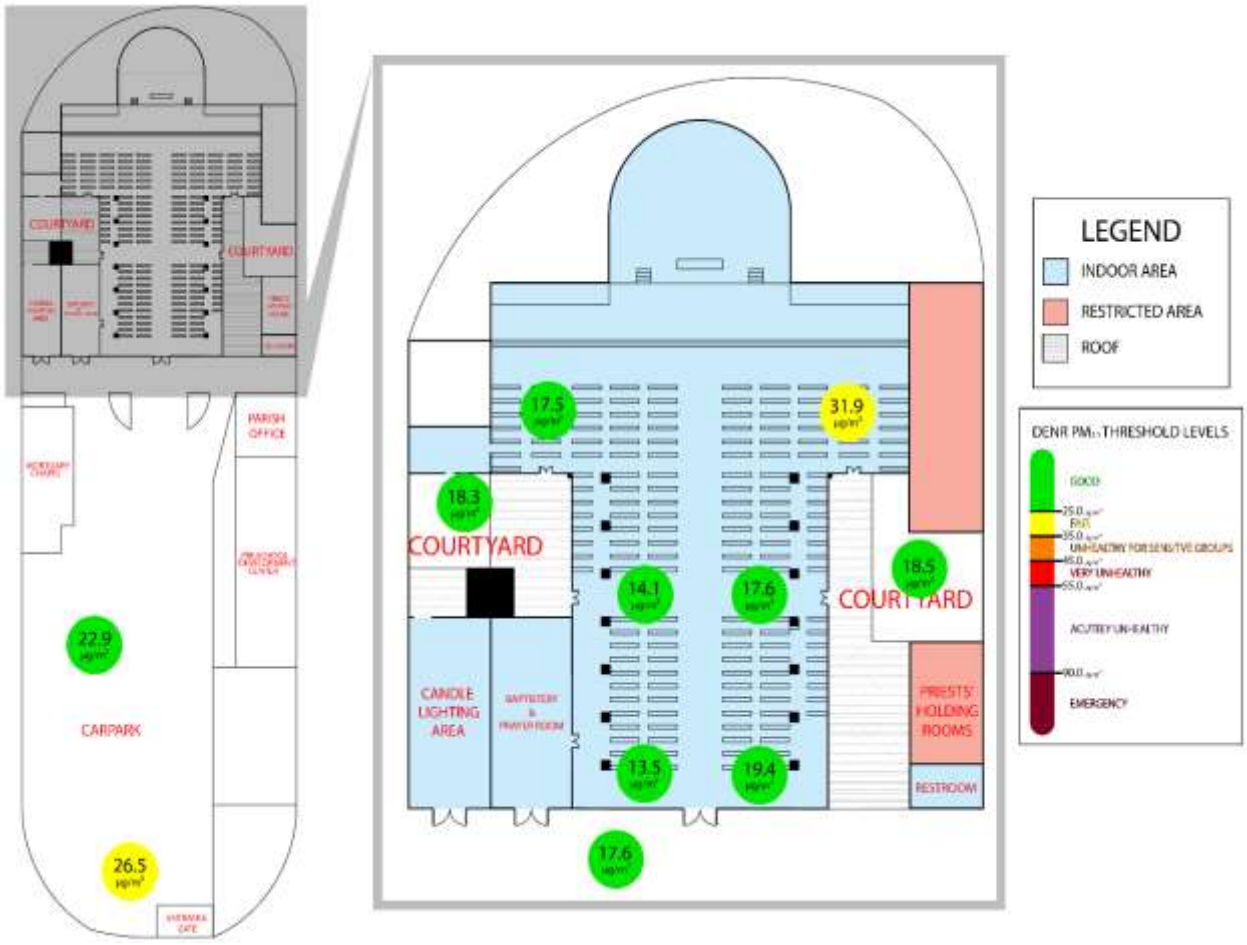

Figure 3.3.1 *Overall $PM_{2.5}$ Mean Concentrations Across Various Sampling Spots.*

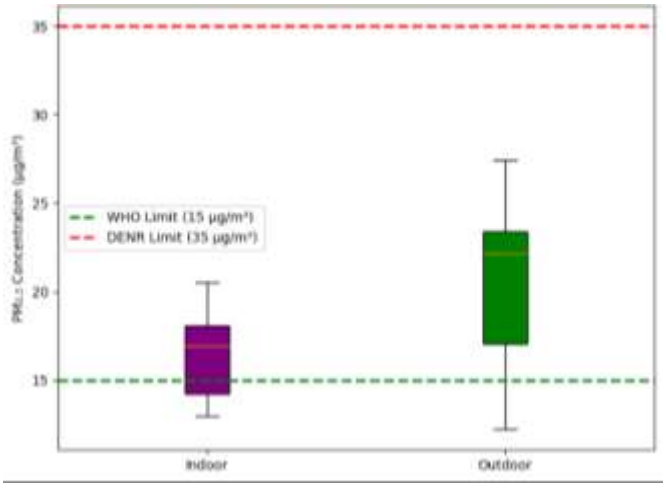

Figure 3.3.2. *Differences Between Indoor and Outdoor $PM_{2.5}$ Concentrations During Both Service and Non-service Times.*

Among all indoor sampling spots, Spot 6 recorded the highest mean $PM_{2.5}$ levels at 31.9 µg/m³ (Figure 3.3.3). This could be attributed to its nook layout, which may have trapped particulate matter. Additionally, Spot 6 has only one entry/exit point (grill doors), unlike Spot 1, which has two (grill doors and a side entrance), allowing for better air circulation.

Outdoor $PM_{2.5}$ levels were particularly high near the church entrance gate (Spot E) due to the heavy vehicular traffic especially during services. Furthermore, during non-service times, wind from the right side of the church often carried smoke from nearby residential areas where burning of leaves and other waste were frequently done.

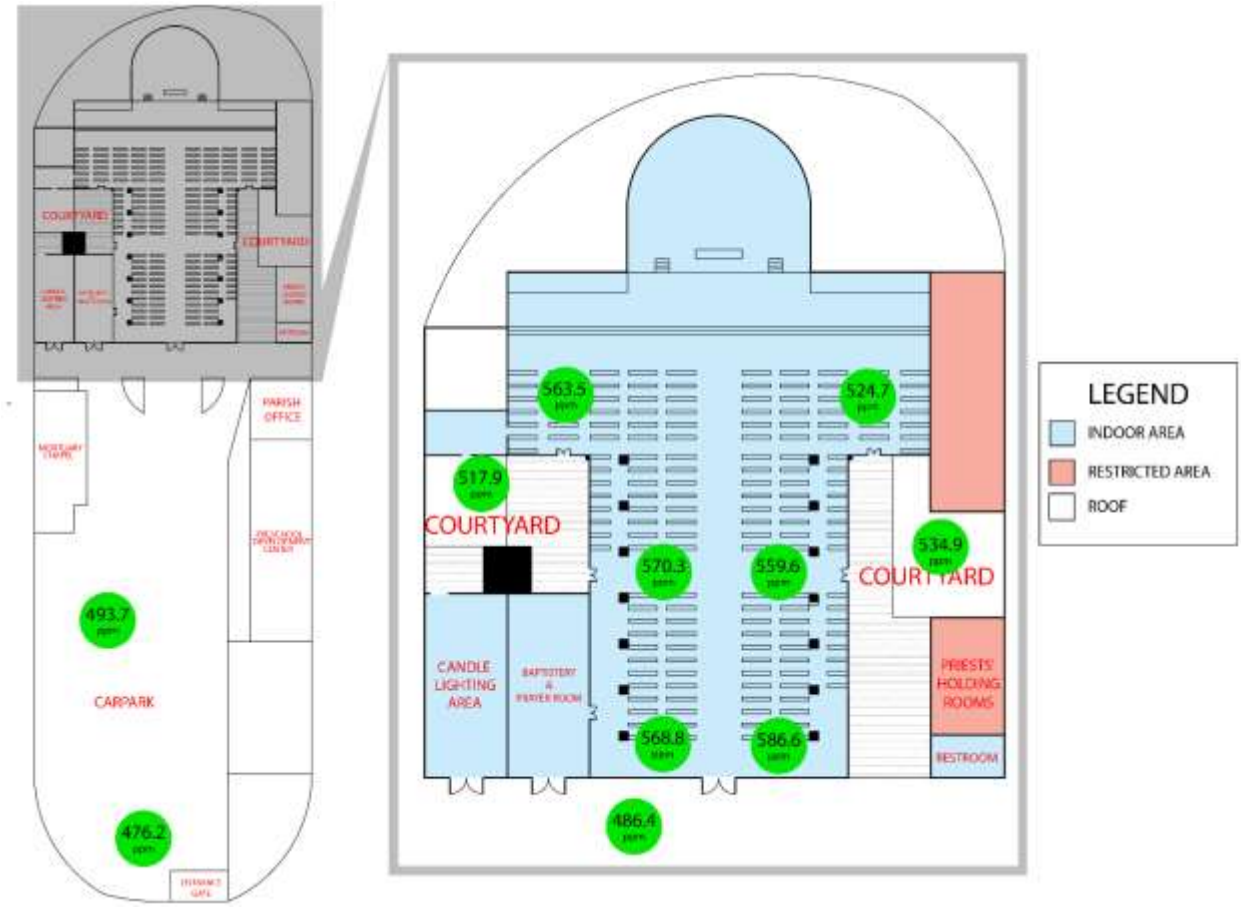

Figure 3.3.3 *Overall CO_2 Mean Concentrations Across Various Sampling Spots.*

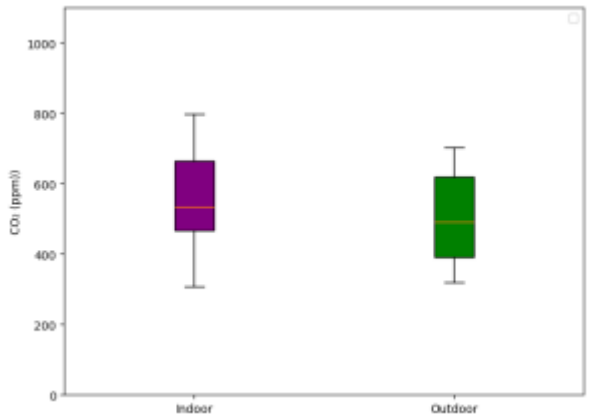

Figure 3.3.4. *Differences Between Indoor and Outdoor CO_2 Concentrations Independent of Service and Non-service Times.*

Independent from service and non-service times, Figure 3.3.4 shows indoor mean CO_2 levels were at 560.1 ppm while outdoor levels were at 501.8 ppm. However, the difference between indoor and outdoor CO_2 concentrations remained statistically insignificant (p=0.169). The open-air design of the church characterized by its grill doors likely allowed CO_2 to disperse efficiently preventing significant buildup indoors.

Notably, indoor CO_2 levels were slightly higher than outdoor levels possibly due to greater human occupancy indoors. Although all measured CO_2 levels remained within acceptable ranges (Pietrucha, 2017), the highest indoor levels were observed near the main entrance (Spots 3 and 4) where people typically enter the church.

To assess outdoor air infiltration and the effectiveness of natural ventilation, indoor/outdoor (I/O) ratios were calculated. An I/O ratio < 1 indicates that outdoor concentrations were higher suggesting effective outdoor air infiltration, while an I/O ratio > 1 suggests the presence of additional indoor CO_2 sources contributing to higher indoor levels (Singh et al., 2024; Song et al., 2015; Stamp et al., 2021).

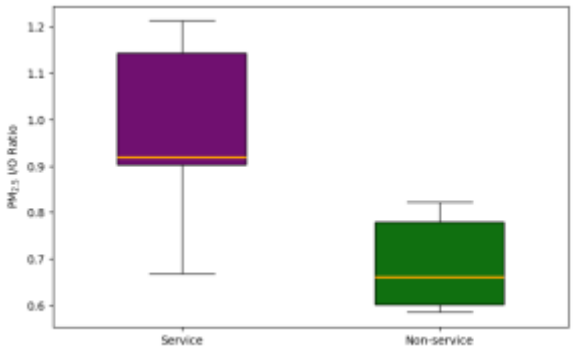

Figure 3.3.5. *Differences in $PM_{2.5}$ I/O Ratios Between Service and Non-service Times.*

As shown in Figure 3.3.5, $PM_{2.5}$ I/O ratios were significantly higher during service times with mean ratio of 0.969 compared to non-service times, which had a mean ratio of 0.670 (p=0.0321). This difference suggests that indoor $PM_{2.5}$ levels were closer to outdoor concentrations during services than during non-service periods. The increase in $PM_{2.5}$ during services can be attributed to high foot traffic, which allowed outdoor air to infiltrate the church as well as the presence of incense burning, which contributed to elevated indoor particulate matter levels as mentioned in Section 3.1. Several factors facilitated the exchange of air between the indoor and outdoor environment of the church during services. The main church door remained open throughout the duration of services, and the presence of grill doors and electric fans helped distribute air within the church. These factors allowed for greater ventilation reducing the difference between indoor and outdoor $PM_{2.5}$ levels.

Among the different locations within the church, the highest I/O ratios during service times were observed at Spot 6 near the altar. This was likely due to its nook layout, which may have allowed particulate matter to accumulate as well as its proximity to the area where incense burning was done. Furthermore, the presence of grill doors and the influence of air from electric fans likely contributed to the increased $PM_{2.5}$ levels in this area. In comparison, the lower $PM_{2.5}$ I/O ratio during non-service times was due to the church's main door being closed and minimal foot traffic wherein both of which limited outdoor air infiltration. Natural airflow during these periods also played a role in the differences in $PM_{2.5}$ concentrations with wind observed to typically blow from the right side of the church to the left side. This airflow pattern contributed to lower I/O ratios on the left side of the church compared to the right. Additionally, during non-service times, there was burning of leaves and other waste outside in a house located relative to the right side of the church, which likely influenced $PM_{2.5}$ levels in that area.

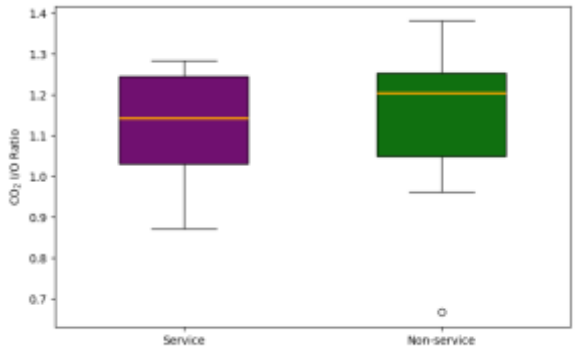

Figure 3.3.6. *Differences in CO_2 I/O Ratios Between Service and Non-service Times.*

Unlike $PM_{2.5}$, as shown in Figure 3.3.6, CO_2 I/O ratios did not show significant differences between service and non-service times ($p=0.942$). The I/O ratio was 1.12 during service times and 1.13 during non-service times, indicating that indoor CO_2 levels remained relatively stable regardless of the amount of human occupancy. This stability may be explained by the ability of CO_2 to diffuse easily in open-air buildings, making its concentration less dependent on the number of people present at any given time. The presence of grill doors allowed air to move freely in and out of the building, which likely helped facilitate efficient CO_2 exchange between the indoor and outdoor environment as indicated in Section 3.2.

Although the I/O ratios during both service and non-service times were slightly higher than 1 suggesting a greater indoor concentration of CO_2, this was likely due to a constant indoor source of CO_2 alongside outdoor infiltration. While human occupancy is a key source of indoor CO_2, the lack of significant differences in CO_2 concentrations between service and non-service times suggests that other factors were responsible for maintaining relatively stable CO_2 levels. Given that human presence varies between service and non-service times, candle lighting appears to be the most probable major contributor to indoor CO_2 emissions. Candles were consistently burned inside the church providing a steady source of CO_2 regardless of whether a service was taking place.

CONCLUSION

The open-air layout of the church was effective in reducing the buildup of indoor pollutants because there were minimal differences between $PM_{2.5}$ and CO_2 levels between service and non-service times, except

for outdoor $PM_{2.5}$ levels during non-service times which was higher than indoor $PM_{2.5}$ levels. Increased outdoor $PM_{2.5}$ levels can be attributed to multiple sources including vehicular activity, industrial activities from a nearby glass factory, cooking emissions from food stalls, and the burning of leaves and waste in the surrounding residential area.

Although $PM_{2.5}$ levels generally exceeded the WHO 24-hour guideline value of 15µg/m³, the $PM_{2.5}$ conditions of the church were still within safe levels based on the 35µg/m³ guideline value set by the DENR. CO_2 levels were also within acceptable ranges, which highlights the importance of ventilation in improving indoor air quality in highly occupied areas such as churches.

Future research may examine the long-term health effects of long-term $PM_{2.5}$ exposure in church environments and explore strategies to further improve air quality especially outdoors. Additionally, expanding the study to include different church designs (airconditioned and non-airconditioned) and seasonal variations would better our understanding of indoor air pollution dynamics in church spaces.

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GREEN SPACES VS. URBAN EMISSIONS: UNDERSTANDING $PM_{2.5}$ PATTERNS IN AN URBAN BUSINESS PARK IN CEBU CITY

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ABSTRACT

We examined the influence of vegetation composition on $PM_{2.5}$ concentrations in urban green zones within an urban business park. Real-time $PM_{2.5}$ data were collected across multiple civic spaces and parklands. While vegetated areas had lower $PM_{2.5}$ levels than non-vegetated sites, statistical analysis found no significant differences between different vegetation compositions or land-use types. Instead, external pollution sources such as vehicular emissions, construction, and waste collection were the primary drivers of $PM_{2.5}$ fluctuations often leading to temporary pollution spikes that exceeded regulatory thresholds. These findings indicate that while urban green spaces provide some mitigation against particulate pollution, their effectiveness is limited when high-emission activities remain unregulated.

Keywords: *Air pollution, Cebu City, Civic Spaces, Environmental health, Parklands, $PM_{2.5}$ Concentration, Green Zones, Vegetation Composition*

INTRODUCTION

Air pollution, particularly fine particulate matter $PM_{2.5}$, poses a significant risk to public health due to its ability to penetrate the respiratory system and affect various bodily functions (Anggraeni & Kusuma, 2023). Studies show $PM_{2.5}$ contributes to respiratory and cardiovascular diseases leading to increased morbidity and mortality rates (Palupi & Abeng, 2023; Schraufnagel, 2020). In densely populated urban areas, $PM_{2.5}$ primarily originates from vehicular emissions and anthropogenic activities (Askariyeh et al., 2020; Nnaji et al., 2023) contributing to concentrations that adversely impact both human health and environmental quality (Lelieveld et al., 2023).

Recognizing the urgency of urban air quality management, cities are increasingly incorporating green zones into development plans as a natural strategy for reducing air pollution (Eshetu et al., 2021; Wolch et al., 2014). In urban environments, green zones composed of trees, shrubs, and grasses have been shown to reduce $PM_{2.5}$ concentrations by capturing airborne pollutants on plant surfaces (Sadiq, 2023; Liu et al., 2023). A study by Wang et al. (2022) across 37 garden cities in

the subtropical monsoon climate zone of China found a significant correlation between green space coverage and lower $PM_{2.5}$ concentrations highlighting the role of vegetation in mitigating air pollution.

In the Philippines, efforts to improve urban air quality have been reinforced by policies such as the Clean Air Act of 1999, which mandates the Department of Environment and Natural Resources (DENR) air quality monitoring and pollution control measures. However, emissions testing by Lu (2022) revealed that many vehicles exceed acceptable emission limits with 99.3% of smoke-belching vehicles failing initial tests, which is a problem exacerbated by the country's aging vehicle fleet with an average age of 15.7 years. Despite these regulatory measures, $PM_{2.5}$ concentrations especially in Cebu City continue to exceed the World Health Organization's (WHO) air quality guidelines, particularly in high-traffic zones (Uy et al., 2023; Tantengco & Guinto, 2022). A study by Uy et al. (2023) found that $PM_{2.5}$ concentrations in Cebu City reached a maximum of 50 $\mu g/m^3$ during construction activities, further emphasizing the role of external pollution sources in air quality degradation.

Within Cebu City's urban business park, green zones have been incorporated as part of environmental and public health initiatives to improve air quality. This study aims to assess the effectiveness of urban vegetation in reducing $PM_{2.5}$ concentrations by evaluating how different vegetation compositions—trees, shrubs, and grasses—influence particulate matter levels.

METHODOLOGY

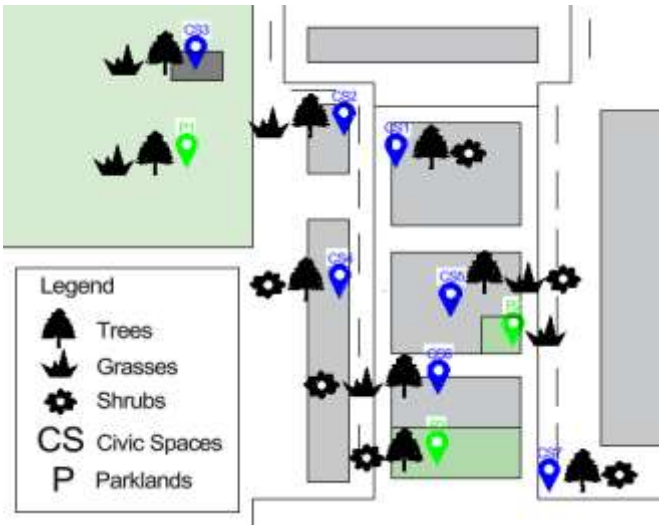


Figure 1. *Map of Green Zones in the Urban Business Park.*

Table 1. *Classification of Vegetation Compositions.*

Trees + Shrubs	Trees + Grasses	Trees + Shrubs + Grasses	Grasses
CS1	*CS2*	*CS5*	*P2*
CS4	*CS3*	*CS6*	
CS7	*P1*		
P3			

Location Determination

The study was conducted within an urban business park in Cebu City, Philippines, an area characterized by commercial activity and mixed-use developments. This setting includes various green zones such as parklands and civic spaces, which feature diverse vegetation compositions. These green spaces serve as natural air pollution buffers, strategically positioned within the urban landscape to help mitigate $PM_{2.5}$ concentrations in a highly developed environment.

Data Collection

Real-time air quality data were collected using the Atmotube Pro, a portable sensor capable of measuring fine particulate matter (PM_1, $PM_{2.5}$, and PM_{10}). Its compact design and real-time monitoring capabilities allowed for efficient and accurate tracking of $PM_{2.5}$ levels across multiple urban green zones (Shittu et al., 2024).

Data collection was conducted over ten non-consecutive visits to each designated monitoring location, between 1:00 p.m. and 4:00 p.m. The time frame was selected due to the observed high volume of vehicular and pedestrian activity in the area. Monitoring sites were strategically chosen based on their proximity to green zones and differences in vegetation composition, ensuring a comprehensive assessment of how vegetation influences $PM_{2.5}$ concentrations.

The Atmotube Pro was positioned approximately 1.2 meters above the ground at each site, and $PM_{2.5}$ concentrations were recorded at one-minute intervals over a five-minute period. This standardized measurement approach minimized variations due to environmental conditions while capturing real-time fluctuations in $PM_{2.5}$ levels.

Data Analysis

Raw data from the Atmotube Pro were transferred via its open API to Microsoft Excel for preliminary data cleaning and storage. Descriptive statistics, including mean values and standard deviations, were calculated, and visual representations of the data were generated to identify trends.

For statistical analysis, the cleaned dataset was imported into Jamovi 2.4.7, an R-based statistical software. A one-way Analysis of Variance (ANOVA) was conducted to compare $PM_{2.5}$ concentrations across different vegetation compositions and locations. Where significant differences were observed ($p<0.05$), post hoc Tukey HSD tests were performed to identify specific group differences. A two-sided p-value < 0.05 was considered statistically significant, ensuring rigorous evaluation of air quality trends across different vegetation types and urban environments.

RESULTS AND DISCUSSION

Temporal Variations in $PM_{2.5}$ Concentrations Aggregated Across All Data Points in the Park

Figure 2 shows the various $PM_{2.5}$ concentrations during different visits to the park throughout mid-2024 to early 2025. $PM_{2.5}$ concentrations varied significantly across different visits as confirmed by a one-way ANOVA analysis ($p<0.05$). The highest recorded concentration was observed during

Visit 4 where $PM_{2.5}$ levels reached 44.8µg/m³, exceeding the Department of Environment and Natural Resources (DENR) threshold of 35.0µg/m³ for "good" air quality. The large spike in Visit 4 suggested that short-term air quality degradation occurs even within urban green zones particularly when multiple pollution sources converge. This increase was attributed to a combination of peak vehicular traffic, increased pedestrian activity, and emissions from nearby businesses (e.g., food stalls). The data collection for this visit took place in the late afternoon (3:00 p.m.), a period coinciding with increased public movement and intensified transportation movement. This finding aligns with previous studies indicating that urban $PM_{2.5}$ concentrations are typically highest during peak traffic hours due to increased vehicular emissions (Askariyeh et al., 2020). Moreover, the $PM_{2.5}$ level recorded during Visit 4 is comparable to concentrations found in high-traffic intersections (Go et al., 2024) further reinforcing the role of transportation emissions as a dominant factor in urban air pollution.

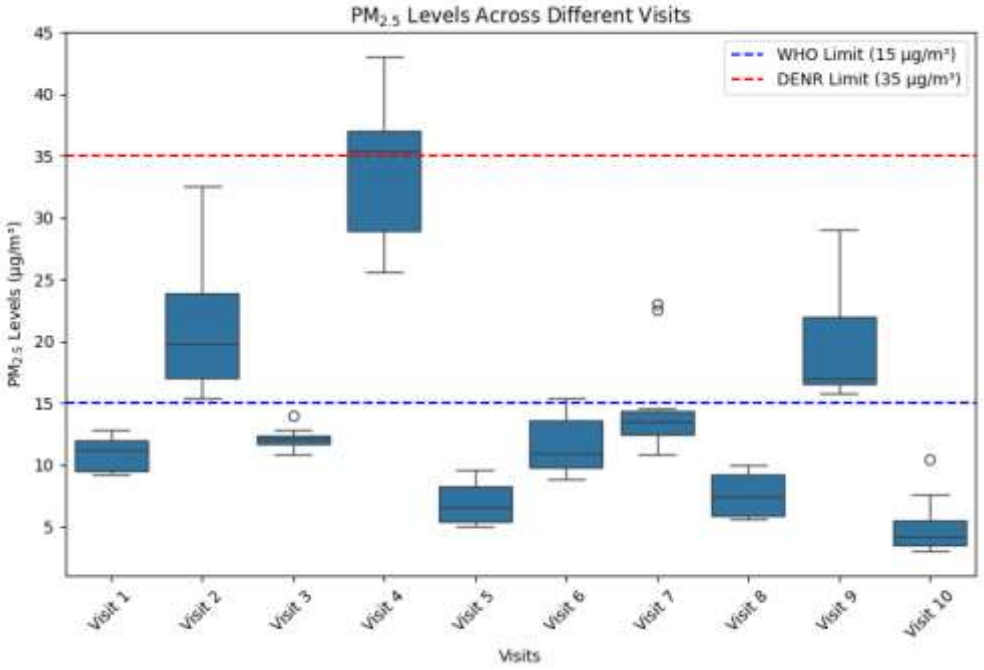


Figure 2. *Temporal Variation in $PM_{2.5}$ Concentration.*

Beyond Visit 4, other visits also exhibited significant fluctuations in $PM_{2.5}$ levels, particularly Visits 2, 7, and 9, which recorded mean concentrations exceeding the World Health Organization's (WHO) good air quality threshold of 15.0µg/m³.

Visit 2 was characterized by ongoing construction activities and the setup for a concert event where both contributed to increased $PM_{2.5}$ concentrations. Construction appeared to generate $PM_{2.5}$ through dust emissions, material handling, and machinery operations, while event preparation increased vehicular traffic and foot traffic which further

exacerbated pollution levels. Visit 7 similarly showed an elevation in $PM_{2.5}$ due to construction work involving heavy equipment and dust-generating activities near the monitored sites. These findings show that construction is a significant contributor to urban air pollution as it releases suspended particulate matter that can linger in the air and affect surrounding areas. Visit 9, on the other hand, showed increased $PM_{2.5}$ concentrations primarily due to emissions from a nearby commercial building and the operation of garbage trucks for waste collection. The collection process itself may have released dust and fine particles into the air, while exhaust emissions from heavy-duty vehicles further contributed to pollution spikes.

While certain visits displayed elevated $PM_{2.5}$ levels, Visits 5, 6, and 10 recorded the lowest $PM_{2.5}$ concentrations all below 12.0 μg/m³. The consistency in low levels during these visits indicates that in the absence of major human-related activities, air quality in the urban green zones remains within the "good" category defined by the DENR. Visit 5 coincided with a period of reduced traffic flow and minimal outdoor activity which helped particulate matter to settle. Visit 6 took place on a day with stable weather conditions and limited pedestrian movement, which likely prevented the resuspension of fine particles. Similarly, Visit 10 did not experience external pollution sources such as cooking emissions, construction dust, or significant human activity, which helped maintain lower $PM_{2.5}$ levels.

A notable insight from these analyses is that while average $PM_{2.5}$ levels remained within regulatory limits during most visits, short-term pollution spikes can significantly impact air quality even in designated green zones. Exposure to elevated $PM_{2.5}$ levels was highest during late afternoon periods (such as 3:00 p.m. in Visit 4) when traffic congestion and construction-related activities were at their peak. It may be beneficial to have some localized air pollution control measures especially when it comes to construction-related activities by, e.g., water spraying the surrounding area to limit particulate dispersion.

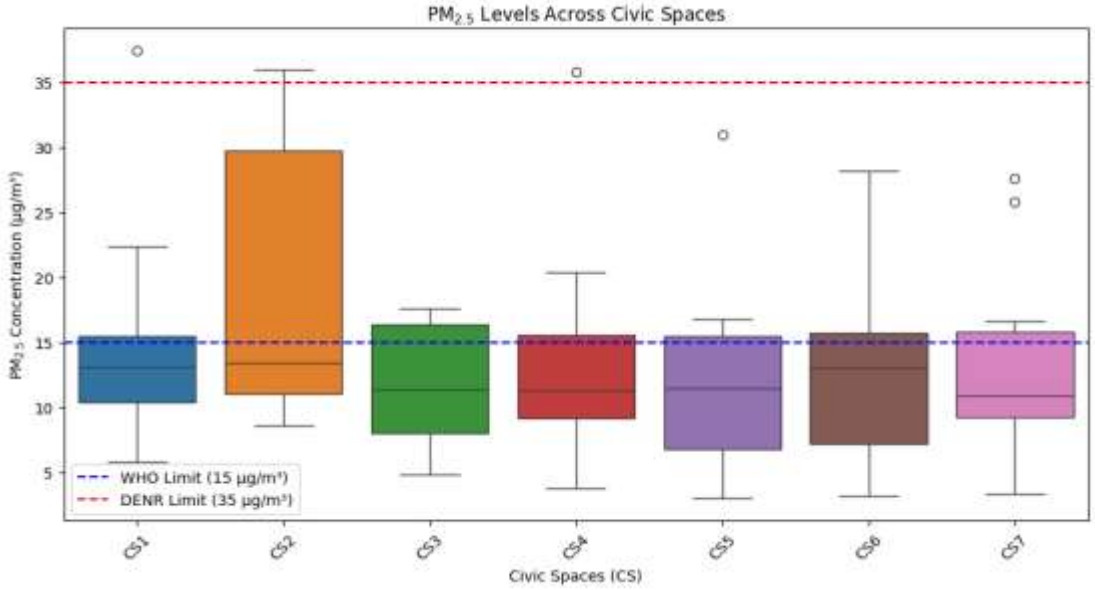


Figure 3. *$PM_{2.5}$ Concentrations between Civic Spaces.*

Spatial Distribution of $PM_{2.5}$ Across Civic Spaces

Figure 3 shows $PM_{2.5}$ concentrations measured across seven distinct civic spaces, each serving different functions such as public transport stops, food parks, pedestrian pathways, and open recreational spaces. The findings reveal that $PM_{2.5}$ concentrations were highest in Civic Spaces 2 and 3 with mean values of 23.2 μg/m³ and 22.8 μg/m³ respectively. These elevated pollution levels, above the acceptable WHO air quality levels, are attributed to vehicular emissions and cooking activities in these areas. However, despite variations in $PM_{2.5}$ levels, ANOVA tests did not identify statistically significant differences among the seven civic spaces, suggesting that while individual locations may experience higher short-term pollution spikes, the overall air quality across the civic spaces remained relatively uniform.

Among the studied locations, Civic Space 2 exhibited the highest $PM_{2.5}$ levels primarily due to its proximity to a bus stop. Public transportation hubs are known sources of particulate pollution as buses and other vehicles emit exhaust gases containing fine particulates, which can accumulate in surrounding areas (Lelieveld et al., 2023). Since the bus stop at Civic Space 2 has frequent arrivals and departures of multiple buses with idling engines, the resulting increase in $PM_{2.5}$ is consistent with previous studies on the impact of transit hubs on urban air quality (Askariyeh et al., 2020). Additionally, the semi-enclosed nature of the civic space with a few trees and multiple nearby buildings may contribute to pollutant retention limiting air circulation and allowing fine particles to persist for extended periods.

Similarly, Civic Space 3 recorded elevated $PM_{2.5}$ concentrations most likely due to emissions from food cooking and preparation. This location functions as an outdoor food park where multiple food stalls operate throughout the day. Several sources of particulate pollution are present in such environments including charcoal grills, gas stoves, and deep fryers, all of which emit fine particles as byproducts of combustion and cooking processes (Liu et al., 2022). The preparation of grilled or fried foods, in particular, has been shown to release high levels of ultrafine particles and organic aerosols, which contribute to localized $PM_{2.5}$ pollution (Shibire et al., 2021).

While Civic Spaces 2 and 3 showed the highest $PM_{2.5}$ concentrations, other locations exhibited relatively moderate pollution levels. For example, Civic Spaces 1, 4, and 5 showed lower mean $PM_{2.5}$ levels, likely due to their greater distance from high-emission sources and better ventilation characteristics. Civic Space 1, for instance, is primarily an open pedestrian walkway with minimal stationary pollution sources allowing natural air flow to help disperse airborne particulates. Similarly, Civic Spaces 4 and 5 are situated further away from major roads and high-foot-traffic areas, limiting exposure to vehicle exhaust and human-induced particle generation. This suggests that spatial positioning within an urban setting plays a significant role in determining local air quality with locations near transportation hubs and commercial activity zones being at higher risk of $PM_{2.5}$ buildup.

Despite the variations in recorded $PM_{2.5}$ levels among the different civic spaces, statistical analysis did not find significant differences among them. These findings indicate that pollution sources have widespread influence with pollutants potentially affecting areas even where direct emissions are minimal. This effect is particularly significant in urban settings where

air pollution rarely stays localized to its source since instead, it spreads across multiple locations, driven by atmospheric mixing and wind patterns (Wang et al., 2022). Short-term pollution spikes in certain civic spaces may be attributed to transient events, such as surges in traffic, public gatherings, or construction activities rather than to permanent structural factors.

Spatial Distribution of $PM_{2.5}$ Across Park Lands: Influence of Land Use and Proximity to Roads

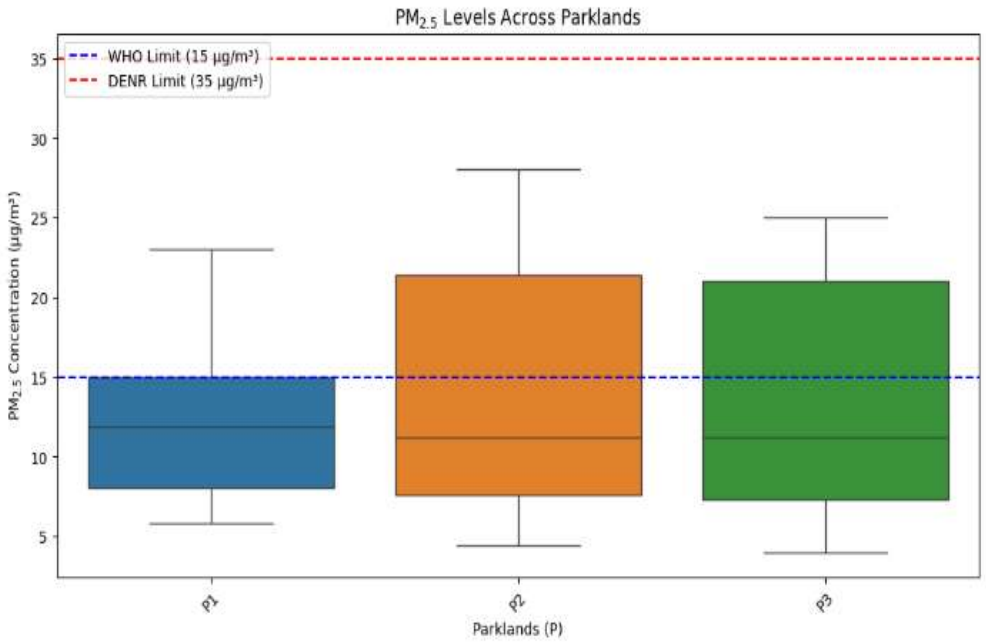


Figure 4. *$PM_{2.5}$ Concentrations between Parklands.*

Looking at Figure 4, $PM_{2.5}$ levels across three parklands reveal that Parkland 3 exhibited the highest recorded $PM_{2.5}$ concentration averaging 16.7 µg/m³. In contrast, Parklands 1 and 2 had slightly lower levels suggesting that spatial factors and pollution sources play a role in shaping air quality within urban green spaces.

A significant factor that appeared to influence $PM_{2.5}$ concentrations in parklands is proximity to waste disposal and transportation infrastructure One of the highest $PM_{2.5}$ levels observed in Parkland 3 can be directly linked to the presence of a large dumpster and active waste collection operations during data collection hours (2:00-3:00 p.m.). The movement of garbage trucks and trash debris disturbances likely contributed to increased particulate matter in the air. Studies have consistently shown that waste collection processes can significantly elevate local $PM_{2.5}$

concentrations due to emissions from diesel-fueled garbage trucks and the resuspension of settled dust (Sakellaris et al., 2023). Additionally, decomposing waste in dumpsters can release airborne organic compounds, which may chemically react to form secondary fine particulates further amplifying pollution levels.

Aside from waste management factors, vehicular emissions were another significant contributor to $PM_{2.5}$ concentrations in parklands. Parkland 2, which is located beside a main road, showed moderate $PM_{2.5}$ levels likely due to direct exposure to vehicle exhaust from passing cars and buses. The consistent exposure of Parkland 2 to roadway emissions coupled with the lack of physical barriers such as trees likely facilitated the continuous penetration of pollutants into the park. This aligns with previous research indicating that parklands situated near high-traffic roads tend to experience higher $PM_{2.5}$ levels due to direct exhaust emissions (Liu et al., 2023).

In contrast, Parkland 1, located near a cluster of restaurants and food stalls, exhibited slightly lower $PM_{2.5}$ concentrations compared to Parkland 3 but still showed noticeable pollution levels barely within the 'good' WHO air quality category. The sources of particulate matter in this parkland likely came from food preparation emissions, foot traffic, and occasional vehicular movement. The observed pollution levels in Parkland 1 indicate that while parklands function as green spaces, their air quality can still be influenced by adjacent commercial activities.

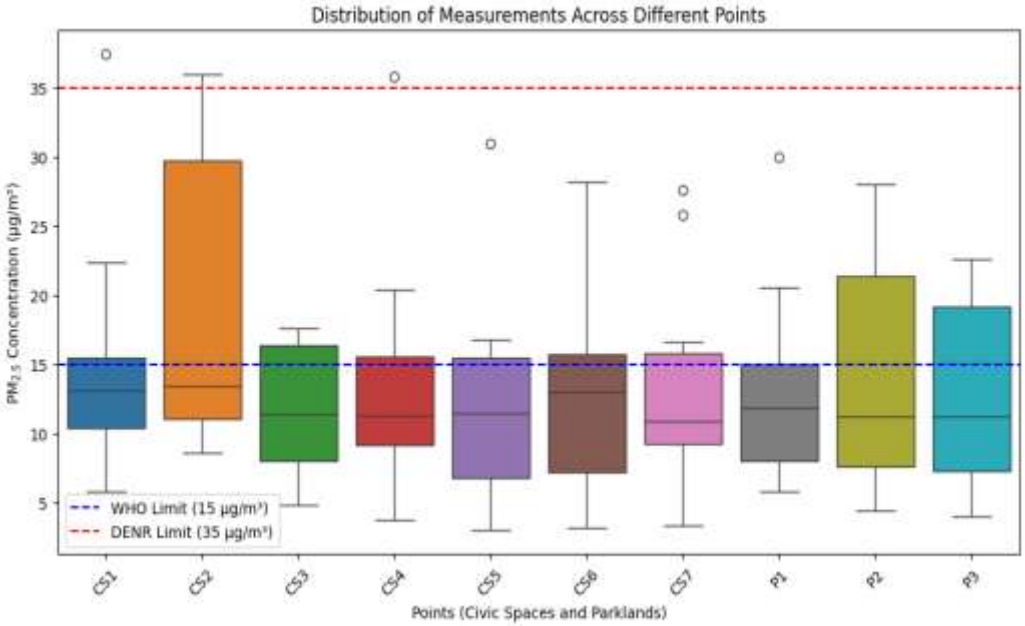
Despite variations in $PM_{2.5}$ concentrations among the three parklands, statistical analysis did not identify significant differences between them. This suggests that while individual pollution sources may create localized variations, parklands as a whole exhibit relatively consistent $PM_{2.5}$ levels, largely dictated by their surrounding urban environment. One possible explanation for the lack of statistical significance is the airflow dynamics within the parklands, which could contribute to the even dispersal of pollutants. Unlike enclosed urban spaces, parks benefit from open-air circulation, allowing airborne particles to disperse more readily rather than accumulating in confined areas. This natural dispersion mechanism might explain why despite being located near different pollution sources, the parklands did not show extreme variations in $PM_{2.5}$ levels and staying within 'good' air quality levels set by DENR.

A key insight with regards to potential intervention of lowering $PM_{2.5}$ concentrations in parklands involves enhancing green infrastructure within parklands to act as a natural barrier against pollution sources. Previous research has shown that dense tree canopies and shrubbery can significantly reduce $PM_{2.5}$ penetration from roadways and industrial sites by trapping airborne particles on leaf surfaces (Wang et al., 2022). In the case of Parkland 2, which is directly adjacent to a major road, the introduction of denser vegetation buffers could help mitigate vehicular emissions. Similarly, in Parkland 3, relocating dumpsters to less frequented areas or implementing enclosed waste management solutions could minimize the impact of waste collection on local air quality.

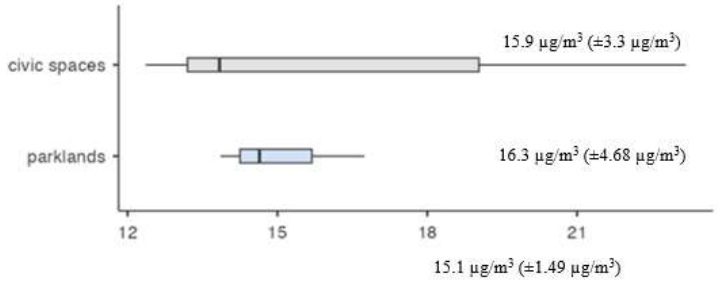
Another interesting insight is to reconsider the placement of high-emission activities near parklands. Given that Parkland 1 experienced moderate $PM_{2.5}$ concentrations due to emissions from nearby restaurants and food vendors, local authorities may explore strategies such as promoting the use of cleaner cooking technologies through using electric grills or improving ventilation in outdoor cooking spaces. Additionally, implementing

air quality monitoring systems within parklands could provide real-time data on pollution levels, allowing for more responsive policy interventions to ensure that urban green spaces remain effective in providing clean air for public use.

Comparative $PM_{2.5}$ Analysis Between Civic Spaces and Parklands



(a)



(b)

Figure 5. *(a) Comparison of $PM_{2.5}$ levels across all measurement areas, and (b) between all parklands and all civic spaces.*

The comparison of $PM_{2.5}$ concentrations between civic spaces and parklands in Figure 5a and 5b provides insights into how different urban land uses influence air quality. Seven civic spaces and three parklands $PM_{2.5}$ concentrations and possible sources were analyzed revealing that while civic spaces exhibited higher $PM_{2.5}$ concentrations, the mean differences between the two site types were not statistically significant. This further suggests that while parklands and civic spaces differ in terms of vegetation coverage and land use, air pollution levels within these areas are influenced by similar external factors, such as traffic emissions, human activities, and localized pollution sources. Despite fluctuations, all $PM_{2.5}$ concentrations remained below the DENR threshold of 35.0 μg/m³ indicating that both civic spaces and parklands fall under the "good" air quality category.

The slightly higher $PM_{2.5}$ concentrations observed in civic spaces can be attributed to their proximity to major roadways, bus stops, and high-foot-traffic areas where vehicle exhaust, dust resuspension, and commercial activities contribute to increased particulate matter levels. Civic Space 2, which was located near a bus stop, recorded the highest $PM_{2.5}$ concentrations and variations among all civic spaces. Additionally, Civic Space 3, located within a food park, also exhibited elevated $PM_{2.5}$ levels due to cooking emissions, supporting research indicating that grilling and frying processes.

In contrast, parklands generally exhibited lower $PM_{2.5}$ concentrations compared to civic spaces (Fig. 5b). However, despite having greater vegetation coverage, parklands were not completely free from air pollution, as external sources still contributed to fluctuations in $PM_{2.5}$ levels. The highest pollution levels in parklands were recorded in Parkland 3, where waste disposal activities and garbage truck operations led to localized $PM_{2.5}$ spikes. Similarly, Parkland 2, which was located adjacent to a major road, was exposed to continuous traffic emissions, leading to moderate pollution levels. These findings indicate that while vegetation in parklands may help reduce airborne particulate matter, proximity to pollution sources is still a determining factor of air quality.

The lack of statistically significant differences in $PM_{2.5}$ levels between civic spaces and parklands suggests that airborne particulate pollution is not strictly confined to specific land use categories but is instead dispersed throughout the urban environment. Several factors could explain this phenomenon. First, wind patterns facilitate the redistribution of fine particulate matter across different locations preventing any one site type from experiencing significantly different pollution levels. This is consistent with prior studies showing that $PM_{2.5}$ concentrations in open urban spaces tend to equalize over time due to natural air circulation (Wang et al., 2022). Second, localized pollution spikes caused by temporary events (such as concerts, construction, and public gatherings) may create short-term fluctuations in $PM_{2.5}$ levels, which obscure long-term trends between civic spaces and parklands.

Although the overall differences in $PM_{2.5}$ levels were not statistically significant, the slightly lower pollution levels in parklands suggest that vegetation plays a role in air quality improvement. Research has shown that trees, shrubs, and grasses can trap airborne particulate matter on leaf surfaces, reducing the amount of $PM_{2.5}$ in the atmosphere (Liu et al., 2023). However, the effectiveness of vegetation in air pollution

reduction depends on factors such as plant species, canopy density, and placement relative to pollution sources. The findings from this study indicate that while vegetation provides some degree of air purification, it is not sufficient to completely counteract pollution from traffic and human activities.

Vegetation Composition and $PM_{2.5}$ Mitigation

Urban green spaces are often regarded as natural air quality regulators with vegetation playing a crucial role in filtering airborne pollutants. This section takes a closer look at Figure 6 and examines how different vegetation compositions influence $PM_{2.5}$ concentrations by analyzing four distinct vegetation types: (1) trees and shrubs, (2) trees and grass, (3) trees, shrubs, and grass combined, and (4) grass alone. The findings revealed that while all vegetated areas exhibited lower $PM_{2.5}$ levels compared to non-vegetated urban spaces, statistical analysis did not identify significant differences in $PM_{2.5}$ concentrations among the four vegetation types ($p=0.616$). This suggests that while vegetation contributes to pollution mitigation, external factors such as proximity to emissions sources, airflow dynamics, and land use patterns play a more dominant role in shaping air quality in urban green zones.

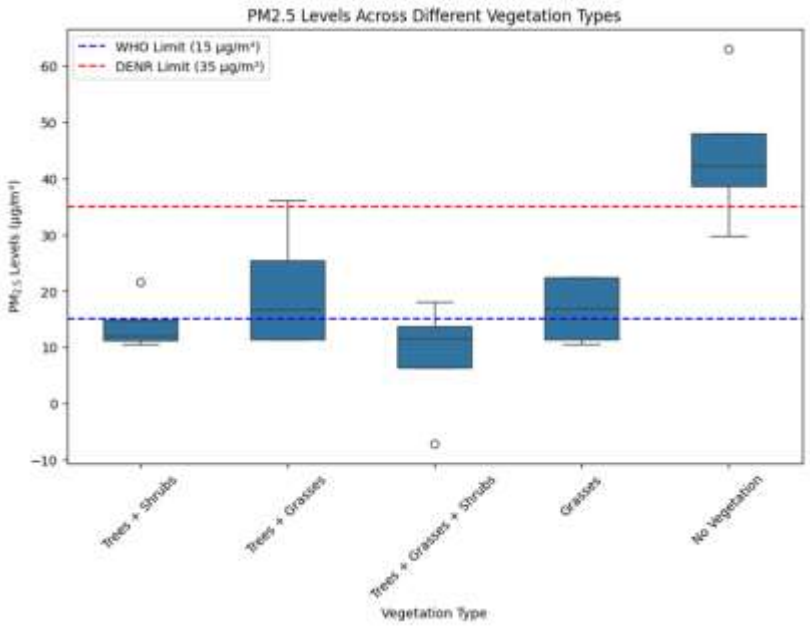


Figure 6. *$PM_{2.5}$ concentrations according to different vegetation points.*

Among the vegetation types, areas with a combination of trees, shrubs, and grass exhibited the lowest $PM_{2.5}$ levels, with a mean concentration of 12.7 µg/m³. The better air quality in these areas aligns with prior research indicating that diverse and layered vegetation structures create more effective particulate matter capture mechanisms (Liu et al., 2023). Trees have large surface areas and dense canopies, which serve as natural air

filters trapping $PM_{2.5}$ on their leaves and bark, while shrubs and grasses help to reduce resuspended dust from the ground (Wang et al., 2022). The combined effect of multiple vegetation layers enhances pollutant capture efficiency, making areas with trees, shrubs, and grasses more effective at mitigating air pollution than those with less diverse vegetation structures.

Interestingly, areas with only grass or trees and grass exhibited relatively higher $PM_{2.5}$ levels compared to multi-layered vegetation compositions. The grass-only sites recorded a mean $PM_{2.5}$ concentration of 16.7 µg/m³, slightly above WHO's "good" air quality level, while areas with trees and grass recorded the highest mean concentration among vegetated areas at 20.20 µg/m³. These findings suggest that while grass provides some level of particulate matter mitigation, its effectiveness is limited by its low height and inability to act as a barrier against airborne pollutants. Furthermore, the site with trees and grass was located near a food park and a bus station, where emissions from cooking activities and public transport likely contributed to elevated $PM_{2.5}$ concentrations. This reinforces the idea that external pollution sources can outweigh the air cleaning benefits of vegetation when they are in close proximity to green spaces.

An interesting comparison was made with a non-vegetated urban area, as reported in Go et al. (2024) in Figure 6, which recorded significantly higher $PM_{2.5}$ concentrations at 44.4 µg/m³. This large difference highlights the benefits of vegetation in reducing $PM_{2.5}$ levels even if differences among specific vegetation types were not statistically significant. The non-vegetated site was located at a high-traffic intersection, where continuous vehicular emissions, lack of pollutant dispersion mechanisms, and surface dust resuspension contributed to unhealthy $PM_{2.5}$ levels. This further supports existing literature demonstrating that urban areas without vegetation tend to experience significantly worse air quality due to the direct impact of emissions and lack of particulate filtration (Sadiq, 2023).

Comparing the various vegetation compositions excluding 'no vegetation' in Figure 6, data suggest that vegetation type and placement still influence $PM_{2.5}$ mitigation to some extent. For example, tree-shrub-grass compositions demonstrated the best $PM_{2.5}$ reduction, which aligns with existing research suggesting that multi-tiered vegetation layers provide better pollutant interception than single-layer systems (Jin et al., 2022). Furthermore, it is possible that factors such as tree species, canopy density, and leaf size play a role in air filtration efficiency though these aspects were not explicitly analyzed in this study.

CONCLUSIONS

This study examined the influence of urban green spaces and vegetation composition on $PM_{2.5}$ concentrations in a highly urbanized setting. While vegetation contributed to lower $PM_{2.5}$ levels compared to non-vegetated areas, statistical analysis found no significant differences between civic spaces and parklands or among different vegetation compositions. However, multi-layered vegetation structures such as areas with trees, shrubs, and grass combined, exhibited the lowest $PM_{2.5}$ levels, suggesting that diverse plant coverage enhances particulate matter filtration. Despite this, the dominant factor influencing $PM_{2.5}$ fluctuations was external pollution sources, particularly vehicular emissions, construction

activity, and waste collection, which caused temporary but significant pollution spikes. Visit 4, for instance, recorded the highest $PM_{2.5}$ level of 44.8 μg/m³, exceeding the DENR threshold of 35.0 μg/m³, showing that human activity and traffic congestion influence poor, short-term air quality even within green zones.

Although parklands had slightly lower $PM_{2.5}$ levels than civic spaces, this difference was not statistically significant, likely due to pollutant dispersion and atmospheric conditions across the urban area. This indicates that air pollution is not confined to specific land-use types but rather spreads depending on wind patterns, urban design, and emission sources. While green spaces provide some mitigation, they cannot independently counteract pollution when high-emission activities are nearby. Enhancing vegetation density near high-traffic zones and pollution sources, enforcing dust control measures at construction sites, and regulating emissions from waste collection and transport hubs could significantly complement the role of green spaces in improving air quality.

While urban greenery contributes to mitigating air pollution, its effectiveness remains constrained without the implementation of complementary emission reduction strategies. Achieving healthier and more sustainable urban environments requires city planning initiatives to integrate vegetation-based solutions with targeted pollution control measures. This approach ensures that green spaces function not merely as aesthetic enhancements but as active buffers against urban air pollution.

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SMARTPHONE-ASSISTED MEASUREMENT OF ACCELERATION DUE TO GRAVITY THROUGH PROJECTILE MOTION: A LOW-COST EXPERIMENTAL APPROACH

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ABSTRACT

This study investigates the use of free smartphone applications in analyzing projectile motion to measure the acceleration due to gravity (g). The experimental setup combines PhyPhox's acoustic stopwatch for time-of-flight measurement, a smart inclinometer for launch angle detection, and a self-constructed projectile launcher. To ensure applicability and reliability, the researcher first validated the setup before it was replicated by seven student groups. The experiment was performed at angles ranging from 0° to 80°, deliberately excluding 90° to maintain valid horizontal displacement data for projectile calculations. Across all groups, the measured values of g exhibited high accuracy, with percentage errors consistently below 2%. Precision was further supported by low standard deviations (ranging from 0.0195 to 0.87) and Coefficients of Variation (CV) as low as 0.16%, indicating strong repeatability. These findings demonstrate that the low-cost, smartphone-assisted system is both effective and reliable for measuring gravitational acceleration, and it offers a practical, accessible instructional tool for enhancing student engagement with two-dimensional motion in physics education.

INTRODUCTION

The acceleration due to gravity, denoted by g, is a fundamental constant that describes the rate at which an object's velocity changes due to the gravitational force. The theoretical magnitude value for g of earth is approximately equal to 9.81 m/s^2. This quantity is crucial for understanding and predicting the motion of objects, as it allows for the calculation of the forces acting upon them and the resulting acceleration (Malthe-Sørenssen, 2015). Despite its significance, directly measuring g can be challenging, especially in classroom settings that lack advanced equipment or tools. Over the years, various methods have been developed to measure g with increasing precision and accuracy, leveraging advancements in technology and experimental techniques. There are various ways of measuring g examples are applying the concept of simple harmonic motion by simple pendulum using smartphone's proximity sensor (Rahmat Hidayat et al 2023) and ambient light sensor as the motion timer for measuring the period

(Pili., & Violanda,. 2018), using the acceleration sensor of smartphones to conduct a free fall experiment (Kuhn, J., & Vogt,. 2013) and applying projectile motion by using tracker video analysis (R Diani et al 2020).

This paper introduces an innovative approach to a classical mechanics laboratory activity, specifically focusing on measuring the acceleration due to gravity through projectile motion experiments in a classroom setting. The approach utilizes acoustic stopwatches, a feature of the smartphone-based application PhyPhox (Physical Phone Experiments), providing an accessible and effective means to measure the time of flight of a projectile without the need for advanced tools such as computer modeling software. Additionally, it incorporates a smart inclinometer for measuring the launch angle and a low-cost, self-constructed projectile launcher. All the smartphone applications used are free to download from both the Google Play Store and the Apple App Store. These activities offer students a hands-on opportunity to explore and discuss the principles of gravity and motion, fostering a deeper understanding of fundamental physics concepts through practical experimentation.

THEORETICAL MODEL

Projectile Motion

Projectile motion is motion of an object being thrown or projected into the air. The thrown object is referred to as a projectile, and its path is referred to as its trajectory. (Fuentes and Larupay 2022).

For the initial position $\vec{s}_o$ and the position of $\vec{s}$ at time *t*, given an initial velocity $\vec{v}_o$ under constant acceleration $\vec{a}$, the equation is expressed as:

$$\vec{s} - \vec{s}_o = \frac{1}{2}\vec{a}t^2 + \vec{v}_o t \qquad (a)$$

This equation can be resolved into two components, the horizontal (x) and vertical (y) components, as the motion occurs in a plane.

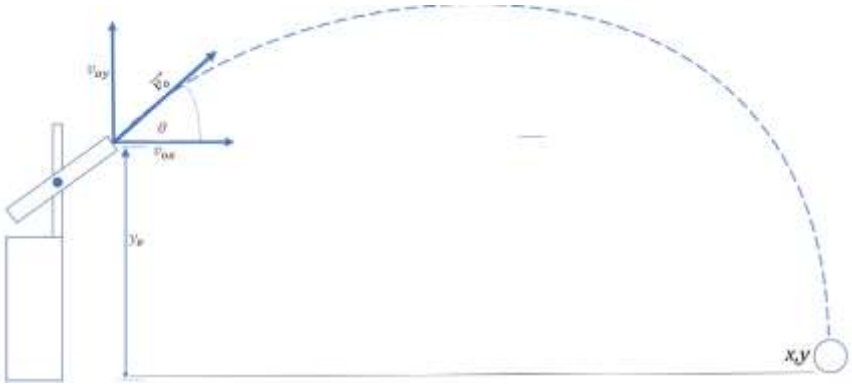

Figure 1: *Launch of a Projectile at an Angle Above the Horizontal.*

Neglecting air resistance, the acceleration in the vertical direction (*y*) is -g, (the acceleration due to gravity), while there is no acceleration in the horizontal direction (a_x=0). Thus, the horizontal and vertical components of position become:

$$x - x_o = v_{o_x} t \qquad (b)$$

$$y - y_o = \frac{1}{2} g t^2 + v_{o_y o} t \qquad (c)$$

The initial velocity components, given the projectile angle θ, are

$$v_{0x} = v_0 \cos\theta \qquad (d)$$

and

$$v_{0y} = v_0 \sin\theta \qquad (e)$$

At x_o=0, combining equation (b) and (d) the equation of time t then,

$$t = \frac{x}{v_o cos\theta} \qquad (f)$$

At level ground y=0 at time t. Combine equation (c) and (e) then is given by

$$-y_o = \frac{1}{2} g t^2 + v_o sin\theta \; t \qquad (g)$$

Combining equations (f) and (g) and the equation of acceleration due g can be expressed as

$$g = \frac{-2(y_0 + x \tan\theta)}{t^2} \qquad (h)$$

where y_0 is the initial vertical position, and x denotes horizontal position at time *t*.

METHOD

A. Construction of Projectile Launcher

The projectile launcher consists of the following components:

- One long straight PVC pipe (20 mm diameter, 17 cm length) used as the horizontal base pipe
- One short straight PVC pipe (20 mm diameter, 13 cm length) serving as the movable launcher arm
- A 90° elbow (L-bow) joint to connect the two straight pipes
- A wooden baseboard (100 × 110 × 15 mm)
- Three PVC pipe clamps with screws to secure the horizontal pipe to the base
- A compression-type spring inserted inside the base pipe
- A string or yarn for pulling and releasing the launcher arm
- A metal washer used to hold the marble inside the launcher

Steps

1. Prepare the Wooden Base by smoothing all edges using sand paper and mark positions to mount the long straight PVC pipe.
2. Place the longer straight pipe flat on the base. Secure it using 3 red pipe clamps and screws. Ensure it is aligned straight and firmly attached.
3. Insert one end of the short (movable) pipe into the elbow joint. The elbow connects this short pipe to the horizontal base pipe, forming an "L" shape.
4. Insert the compression spring into the open end of the horizontal pipe. (see Figure 2)

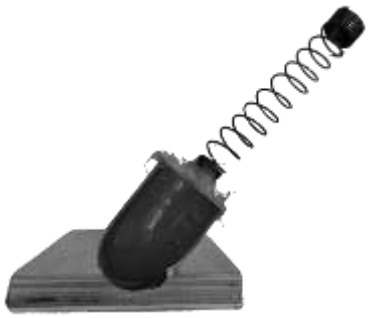

Figure 2: *Attachment of the compression spring.*

5. Slide the movable launcher pipe (connected to the elbow) into the base pipe, so the spring sits inside, between the two pipes. Ensure the spring isn't too loose. It should fit snugly and slide smoothly when compressed.
6. Tie one end of the string around the movable pipe, near the elbow. Tie a washer or loop at the other end of the string. This allows you to pull back the launcher pipe (compressing the spring) and release it to launch.

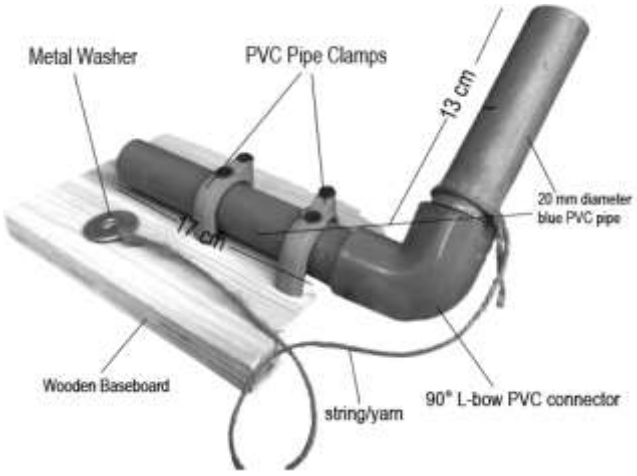

Figure 3: *Self-Constructed Projectile Launcher.*

B. Experiment

Materials

Smartphone with Phyphox application and smart inclinometer
Marble
Clamp
Measuring tape
Carbon paper A4 size
Bondpaper
Plumb bob
Self-made Projectile launcher

Procedure

1. Securely clamp the Projectile Launcher to a sturdy horizontal surface (e.g., lab table), ensuring it is stable and near the edge of the table. Refer to Figure 4 for proper placement.

Figure 4: *Clamping of the Projectile Launcher.*

2. Use the smartphone with the Smart Inclinometer app to measure the angle of release. Begin with a release angle of 0º and increase it in 5ºincrements for subsequent trials. (Refer to Figure 5 for smartphone positioning.)

Figure 5: *Position of Smartphone with the Smart Inclinometer App.*

3. Adjust the angle of the launcher by rotating it to the desired angle.
4. Use the plumb bob to locate the point on the floor directly beneath the ball's release point in the launcher. Mark this as the reference point for horizontal distance x measurements.
5. Measure and record the initial vertical position y_o from the bottom of the ball at the release point to the floor. Note that will y_o vary with each change in the release angle.
6. Load the marble into the launcher and secure it using the loader. Lock the trigger by inserting a washer in place before firing.
7. Fire a test shot to identify the landing point of the marble on the floor. Place a piece of bond paper at this location, secured with tape, and overlay it with carbon paper (carbon-side down). This setup will leave a mark on the paper when the marble hits the ground.
8. Fire three shots for each angle setting. Record the time of flight (t) for each shot, then compute the average time of flight.
9. To measure the time of flight, open the Phyphox app, navigate to the Timers section, and select Acoustic Stopwatch.
10. Set the sound threshold to 0.4 a.u. (adjust if necessary, based on sensitivity).
11. Position the smartphone near both the launcher and the landing point. Ensure a quiet environment to minimize interference.
12. Press Reset on the app before each shot to ensure accurate timing.
13. Measure the horizontal distance x for each shot from the release point to the marked landing position on the paper. Record these values.
14. Calculate the acceleration due to gravity g using equation (h) using the measured values of θ, y_o and average x ,and t.

15. Calculate the percentage error $\frac{|9.81-measured\ g|}{9.81} \times 100$
16. Calculate the standard deviation and the Coefficient of Variation (CV).
17. Record the data in Table 1.

Notes

1. Ensure the launcher is stable during all trials to maintain consistent results.
2. Conduct the experiment in a quiet environment to improve the accuracy of acoustic time measurements.

Table 1

	Initial vertical displacement (y_o)	Time of flight (t)				Horizontal displacement (x)				Average Acceleration due to gravity (g)	Uncertainty
Projectile Angle		Trial 1	Trial 2	Trial 3	Average time	Trial 1	Trial 2	Trial 3	Average Horizontal displacement		
0º											
5º											
10º											
15º											
20º											
25º											
30º											
35º											
40º											
45º											
50º											
55º											
60º											
65º											
70º											
75º											
80º											
Average											
Standard Deviation (σ)											
Coefficient of Variation (CV)											

DATA AND RESULTS

***Table 2**: Measured Average Acceleration due to gravity of 7 groups of students and the researcher.*

Projectile Angle	**Measured Average Acceleration Due to Gravity (g)**							
	Researcher	*Group 1*	*Group 2*	*Group 3*	*Group 4*	*Group 5*	*Group 6*	*Group 7*
0º	9.81	9.84	9.84	9.90	9.84	9.84	9.84	9.84
5º	9.80	10.18	9.98	9.83	9.91	10.11	10.10	9.95
10º	9.79	9.76	10.03	9.86	10.15	10.21	10.11	9.71
15 º	9.82	11.16	10.31	10.03	9.63	9.44	9.96	10.22
20 º	9.77	9.91	10.05	10.07	9.89	9.72	10.21	9.28
25 º	9.84	10.51	9.35	9.81	9.88	9.32	9.68	9.43
30 º	9.81	9.64	10.19	9.88	10.07	9.86	9.97	9.92
35 º	9.81	9.98	10.23	9.83	9.93	9.57	10.31	10.23
40 º	9.82	9.83	9.79	9.72	9.74	9.32	9.94	10.15
45 º	9.84	10.58	9.90	9.90	10.10	9.73	9.83	9.82
50 º	9.81	9.48	10.18	9.87	9.88	9.91	10.23	10.21
55 º	9.81	9.83	9.71	9.82	9.70	9.64	9.76	9.88
60 º	9.80	9.82	9.85	10.11	9.82	9.76	10.46	9.98
65 º	9.79	10.32	9.86	9.86	10.25	10.05	10.28	9.43
70 º	9.78	9.88	10.06	9.89	9.95	9.72	9.31	9.88
75 º	9.82	9.87	9.84	9.82	9.70	9.39	9.34	9.95
80 º	9.84	9.22	9.64	9.83	10.38	9.97	9.71	9.95
Measured Average g	*9.81*	*9.98*	*9.90*	*9.89*	*9.93*	*9.74*	*9.94*	*9.87*
Average % error	0.14%	1.76%	0.87%	0.77%	1.22	0.72	1.36%	0.63
Standard Deviation (σ)	0.0195	0.46	0.87	0.10	0.20	0.27	0.32	0.28
Coefficient of Variation (CV)	0.2%	4.61%	8.79%	1.01%	2.01%	2.77%	3.2%	2.83%

Table 2 presents the measured average acceleration due to gravity at different angle of release measured by the researcher and the seven groups of Industrial Engineering students enrolled in Physics for Engineers of school year 2024-2025. The experiment utilized a self-constructed projectile launcher and smartphone applications namely, an acoustic stopwatch of PhyPhox and smart inclinometer to compute gravitational acceleration based on the principles of projectile motion. The angle of projection was varied systematically from 0° to 80° in 5° increments. This range was selected to comprehensively assess the projectile's parabolic motion and its effect on the calculated value of gravitational acceleration. A 90° launch angle was intentionally excluded

because at 90°, the projectile moves purely vertically. In such a case, the horizontal displacement becomes negligible or zero, rendering the core equation for horizontal projectile motion inapplicable or indeterminate. Including only angles from 0° to 80° ensured that both horizontal and vertical components of motion were present, allowing the use of derived kinematic equations to compute *g*.

The researcher's data served as the baseline for accuracy and consistency, with an average measured gravitational acceleration of 9.81 m/s², a standard deviation of 0.0195, and a Coefficient of Variation (CV) of only 0.2%, confirming both high precision and excellent agreement with the theoretical value.

Across the student groups, measured values of *g* varied due to expected experimental limitations and procedural inconsistencies. Group 1 recorded an average of 9.98 m/s², with the CV of 4.61% and a standard deviation of 0.46, indicating relatively high variability among trials. This may be attributed to inconsistent timing or errors in measuring the angle of release. Group 2 showed the least consistent results with a standard deviation of 0.87 and the highest CV of 8.79%, despite a reasonable average *g* value of 9.90 m/s². The high variability suggests procedural discrepancies, possibly due to noise interference in the acoustic stopwatch or misalignment during launch. Group 3 had the most precise and accurate student data, with a mean of 9.89 m/s², a standard deviation of 0.10, and a CV of 1.01%. These results reflect strong procedural execution and effective use of measurement tools. Group 4 also produced reliable data, with a mean of 9.93 m/s², SD of 0.20, and a CV of 2.01%. Groups 5, 6, and 7 exhibited moderate precision, with CVs ranging from 2.77% to 3.2% and mean values between 9.74 m/s² and 9.94 m/s². These values suggest generally sound methods with minor inconsistencies, possibly in release coordination or smartphone placement during timing. Despite the variances, all groups obtained mean values of g within a reasonable range of the accepted standard (9.81 m/s²), with percentage errors all below 2%. This confirms the feasibility of using smartphone sensors and self-made apparatus for educational physics experiments, offering both accessibility and pedagogical value.

CONCLUSION

This study successfully demonstrated the viability of using free smartphone applications in conjunction with a self-constructed projectile launcher to measure the acceleration due to gravity (g) through projectile motion. The system, which incorporated PhyPhox's acoustic stopwatch and a smart inclinometer, proved to be both cost-effective and educationally enriching. The experimental results yielded high levels of accuracy and precision, with all student groups obtaining average g-values within 2% of the accepted standard value of 9.81 m/s². The low standard deviations and coefficients of variation among the trials indicate that the method is not only accurate but also repeatable when properly executed. These outcomes validate the use of smartphone-assisted physics experiments in classroom settings, particularly where access to advanced laboratory equipment is limited.

RECOMMENDATION

Given the success of this low-cost experimental approach, it is recommended that educators in physics and related fields consider integrating smartphone-based experiments into their curriculum to promote

active, inquiry-based learning. Future implementations should emphasize careful calibration, environmental control, minimizing ambient noise, and consistent measurement procedures to reduce variability.

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PHILIPPINE PHYSICS SOCIETY (PPS)

47th Annual National Physics Seminar-Workshop/Convention
38th National Physics Olympics
33rd National Physics Fair
March 25-28, 2025

FOUNDATION UNIVERSITY
Dumaguete City, Negros Oriental

Theme: PPS@51: *Physics for Advancing Eco-Friendly Innovations*

.

ABSTRACTS OF PRESENTATIONS

P1. LIGHT-EMITTING DIODE IN A SIMPLE CIRCUIT

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Today's lighting technology makes extensive use of light-emitting diodes, or LEDs. Compared to incandescent light bulbs, they use less energy and last longer. They come in a variety of colors and are unquestionably popular as the go-to option for home lighting and special occasions, such as Christmas lights. LEDs are popular in schools and are utilized in robotics and student projects. As popular as they are, it is interesting to know what an LED is and how it works.

In this presentation, the concept that explains the workings of an LED is discussed. So as not to burn them, LEDs require a resistor to limit the current when the voltage is high. A sample calculation of the required resistance of the resistor used in the circuit is also presented. The participants are also given practical experience building a basic circuit with an LED as a load in order to improve understanding.
(2 hrs-Lab)

P2. HUYGENS' PRINCIPLE AND THE SINGLE-SLIT DIFFRACTION

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Light diffracts around the corners of an obstacle or opening and shows interference fringes when the opening is a narrow slit. This diffraction pattern demonstrates that light is a wave. In this presentation, Huygens' principle is discussed. After the discussion of the principle, a single-slit diffraction setup is introduced and demonstrated. Included in the demonstration are the construction of the set-up and the materials used. (1hr)

P3. DIY SPECTROPHOTOMETER: USING CELL PHONE FOR LIGHT ANALYSIS

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This presentation explores the fundamental principles of spectrophotometry, a method for measuring light absorption and transmission by substances at specific wavelengths. It demonstrates how a basic spectrophotometer can be constructed using a cell phone to observe how visible light interacts with various colored solutions. (LAB 1-hour)

P4. EXPLORING THE EFFECT OF ELECTRICITY ON PH IN SALT SOLUTIONS

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This presentation is inspired by the idea, "Water and electricity don't mix." However, in this demonstration, we'll bring them together to create something remarkable: two separate

solutions – one acidic and the other basic. While the setup is simple, its chemistry is intricate, opening the door to exciting opportunities for exploration and understanding. (Lab. 1 hr)

P5. MEASURING THE SURFACE TENSION IN WATER

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When you dip your finger into water and pull it out, the water pulls back on you due to surface tension, which arises from the cohesive forces between water molecules. In this demonstration, we'll explore surface tension in action and use basic principles of chemistry and physics to measure the strength of this force. (Lab – 1 hour)

P6. CONSTRUCTING A RAFT POWERED BY SURFACE TENSION

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The ability of a water strider to walk on water and the effectiveness of detergent in cleaning dishes are both linked to an intriguing property of water: surface tension. This phenomenon, created by the cohesive forces between water molecules, is crucial in many everyday occurrences. In this demonstration, we'll explore the principles behind surface tension and its practical applications in daily life. (Lab – 1 hour)

P7. EXPLORING THE ENERGY IN FOOD: MEASURING CALORIES THROUGH COMBUSTION

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Nutritionists determine the number of Calories in food by measuring its chemical energy. In this demonstration, we'll explore a method for calculating the energy content of different foods

by building a simple calorimeter. Using this device, we'll capture the heat released when burning a small food item, such as a nut or a piece of popcorn. This process highlights the principles of energy transfer and combustion, giving a whole new meaning to the phrase "burning calories!" (Lab – 1 hour)

P8. INTERACTIVE PHYSICS TOYS IN TEACHING BASIC CONCEPTS OF LINEAR MOTION

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Grade 7 and 8 students did not receive adequate instruction on the fundamental concepts of linear motion due to the impact of the pandemic. This study aimed to examine the effectiveness of incorporating self-made interactive physics toys, such as a toy car with a string and beads, a balloon-powered toy car, and an acceleration toy car, in teaching the basic concepts of linear motion to 7th and 8th-grade students. The researcher employed a quasi-experimental design, specifically a one-group pretest-posttest design. Statistical tools such as percentage, mean, standard deviation, weighted mean, t-test for dependent data, and Spearman Rank-Order Correlation were used for data analysis. The study involved 21 students, divided into 7 groups with 3 members each. The results indicated a "fairly satisfactory" performance in the pretest and a "very satisfactory" performance in the posttest, with the difference in their performances being statistically significant. Additionally, the students demonstrated a "very high" level of interest in using the three self-made interactive physics toys. Finally, a moderate and significant correlation was found between the students' interest in using the interactive toys and their posttest performance.

Keywords: Physics, self-made interactive physics toys, interest, instructional approach (1-hour)

P9. TRADITIONAL FLIPPED CLASSROOM VERSUS LECTURE-BASED INSTRUCTION IN ENHANCING SCIENCE 9 PHYSICS

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This study explored the effectiveness of both the traditional flipped classroom and lecture-based instruction in enhancing Grade 9 students' understanding of physics concepts covered during the fourth grading period at Bais City National Science High School during the school year 2023-2024. The true experimental design was used in this study and the one-stage cluster sampling technique was applied, involving 61 students randomly assigned to experimental and control groups. The two groups of students had similar levels of knowledge based on their prior performance in Third Quarter Science 9. The researcher used the Mean Performance Score (MPS) to verify their equal expertise in science. This was ensured using a t-test: Two-Sample Assuming Equal Variances. For data treatment, the researcher employed the Mean, T-test for dependent data, and T-test for independent data. The findings revealed that both methods significantly improved student performance, with the traditional flipped classroom instruction group showing a higher post-test performance than the lecture-based instruction group. The study concluded that the traditional flipped classroom is a more effective strategy for fostering active learning and improving comprehension of physics, particularly in topics like projectile motion, impulse and momentum, conservation of linear momentum, and conservation of mechanical energy.

Keywords: traditional flipped classroom, lecture-based instruction, physics education, active learning (1-hour)

P10. TEACHING WAVE CONCEPTS USING SELF-MADE WAVE MACHINE AND COMPUTER SIMULATOR

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This study aimed to investigate the effectiveness of utilizing a self-made wave machine and a computer simulator in teaching basic concepts of waves to Grade 7 students. Drawing on Schwab's Inquiry based Learning Theory, the research explored how these hands-on and technology-based approaches impact student performance and interest in science education. The researcher used descriptive-correlational and comparative designs. A total of 109 students utilized the self-made wave machine, and 110 students used the computer simulator. These approaches were randomly assigned to the two groups of students. The findings revealed that the students' performances after using the self-made wave machine and computer simulator were both at the "outstanding" level. The data also indicated no significant difference in the students' performances after using the self-made wave machine and computer simulator. Furthermore, students' interest in using the self-made wave machine and computer simulator was generally "high." Lastly, no significant relationship was found between students' interest in activities using self-made wave machine and computer simulator and their performance. These findings suggest that hands-on and digital methods can effectively support science learning, providing educators with versatile tools to engage students. Incorporating self-made apparatus and simulators in science education may

enhance student engagement and understanding without significantly altering performance outcomes.

Keywords: Computer simulator; Educational technology; Science education; Self-made wave machine; Wave phenomena. (1 hour)

P11. CONCEPT MAPPING STRATEGY AND PERFOMANCE OF STUDENTS IN COLLEGE PHYSICS

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This study investigated the effect of concept mapping on the performance of students in physics especially on transfer test on kinematics and dynamics.

An experimental pretest-posttest control group design was used in this study. Two intact classes served as research subjects and were randomly assigned as experimental and control groups. The experimental group was introduced to the concept mapping strategy and taught the techniques of constructing concept map. Students in the control group used the "hybrid" traditional method that included exposition, analogy, peer tutoring and discussion.

The findings of the study revealed that the students in the experimental and control groups had similar cognitive understanding of the concepts on kinematics and dynamics before the experiment. After the intervention, the students in the experimental group significantly scored higher compared to those in the control group. Concept mapping enabled students to engage in higher order thinking skills such as comprehension, analysis, and application. There is evidence that concept mapping provided students an opportunity to engage in cognitive processes such as attending to relevant information about kinematics and dynamics, mentally organizing information to coherent structure, and integrating to prior knowledge about motion and forces. This resulted to better retention and better performance of students in the transfer test. Concept mapping, therefore, is a better teaching strategy and an effective learning tool than the traditional method in teaching and learning physics specifically on kinematics and dynamics.

P12. VGG-16 WITH HARRIS AS ACTIVATION FUNCTION FOR IMAGE CLASSIFICATION

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Deep transfer learning is a technique wherein the pre-trained layer from a generic network is being transferred to a task-specific network which enables the network to learn fast and at high

accuracy for image classification. VGG-16 is well-known convolutional neural network (CNN) model for transfer learning with ReLU as its activation function. Activation functions help the deep neural networks (DNNs) improve its performance by introducing non-linearity and complexity to the network. In this paper, we apply the Harris as an activation function for VGG-16 and compare its image classification performance to ReLU. The results show that the target training and testing accuracy was surpassed by Harris when α=-0.50 and comparing its F1-score it was able to surpass the ReLU's performance in classifying images in most of the classes of CIFAR-10.

Keywords: Transfer learning, VGG-16, Activation Function, Harris, ReLU

P13. ENTROPY IN ACTION: INTERACTIVE CLASSROOM ACTIVITIES BRIDGING PHYSICS AND SOCIAL CHANGE

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Entropy is not just about heat and disorder in physics -it is also a powerful lens for understanding how societies change, adapt, or collapse. This lecture explores how entropy bridges Physics, Political Science, and Social Science, making learning more engaging and relevant through interactive classroom activities. Participants will discover hands-on methods such as modeling revolutions with gas particles, simulating societal collapse with sandpiles, and analyzing how innovation counteracts disorder. These activities help students visualize how natural laws shape human systems, fostering critical thinking, interdisciplinary connections, and real-world applications. By integrating scientific principles with social phenomena, educators can create dynamic, thought-provoking lessons that make complex concepts more accessible and meaningful.

P14. EVALUATING THE IMPACT OF VARYING PROCESSING POWERS ON DATA ACCURACY IN PHYPHOX'S ACOUSTIC STOPWATCH MEASUREMENTS

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As smartphones becoming increasingly powerful, they have become increasingly viable tools for scientific measurements. This study investigates the accuracy of different smartphones in measuring time intervals using the Phyphox program and its Acoustic Stopwatch feature, an open-source mobile application for physics experiments. The goal of this experiment is to identify whether the processing speed of phones affects data collection. The experiment involved recording

metronome ticks at varying frequencies using multiple smartphones to assess timing accuracy. Each phone did 50 trials in various metronome frequencies (60Hz, 90Hz, 120Hz, and 240Hz) in a controlled, low-noise, echoless environment. The accuracy of each device was determined by analyzing deviations in recorded time intervals. Results indicate that the Realme 6 exhibited the highest precision with the lowest deviations reaching 12.9 μs, while the Huawei Y9 Prime produced high deviations up to 360 μs. These findings suggest that smartphones with processing power equal to or greater than the Realme 6 can reliably generate accurate time measurements. Devices with weaker processing power than the Realme 6, such as the Huawei Y9 Prime, may introduce significant measurement errors. This study highlights the importance of processing power in smartphone-based scientific experiments. In conducting experiments, it is suggested to use phones with higher processing power to reduce deviations in data.

Keywords: Phyphox, smart phone, acoustic stopwatch, processing power, error measurement

P15. PARALLEL PLATE CAPACITOR

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This demonstration will verify the capacitance formula for a parallel plate capacitor. The model improvised parallel plate capacitor used in this demonstration has square plates, 14.2 cm on an edge (A=0.0200 meter^2.); one is fixed in place and the other movable. By sliding the movable plate sideways, the effective area A of the plates can vary from maximum to effectively zero meter2. The movable plate may be placed in different grooves in the apparatus, allowing different plate separation, S. The minimum separation is 2.0 mm and this may be increased in steps of 2.0 mm. Some dielectric material will also be used to see its effect on the parallel plate capacitor's capacitance. The capacitance of the plates is measured by using a multimeter.

P16. MODELING THE IMPACT OF PRICE AND AVAILABILITY OF ITEMS ON STUDENT SHOPPING CHOICES: VSU CAMPUS MARKET VS. BAYBAY CITY ESTABLISHMENTS

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This study investigates the purchasing behaviors of students at Visayas State University (VSU), specifically examining their choices between shopping at the on-campus market versus off-campus establishments in Baybay City Proper. Using an Agent-Based Model (ABM), the study simulates decision-making processes where students assess factors like price, availability, and distance to optimize their purchasing decisions. Results show that students are highly sensitive to

price changes and item availability. When items at the campus market are cheaper and readily available, there is a significant increase in the number of students choosing to shop on-campus. Conversely, higher prices and lower availability at the VSU market drives students to seek alternatives off-campus, even at the expense of higher travel costs. This interplay of factors emphasizes that both affordability and consistent stock availability are essential for attracting student consumers. By adjusting prices and ensuring a steady inventory, campus vendors can meet the needs of the student population, reduce off-campus reliance, and enhance overall market utilization within the university.

Keywords: Agent-based Model, Market Modelling

P17. FROM UPCYCLED MATERIALS TO INSIGHT: DIY SPECTROSCOPE IN ACTION – QUALITATIVE AND QUANTITATIVE ANALYSIS OF SPECTROSCOPY DATA USING DIY SPECTROSCOPE VERSUS SPECTROVIS PLUS WITH LOGGERPRO ANALYSIS

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The workshop-research presentation will have two parts: (1) the construction of a DIY Spectrocope from upcycled materials, and (2) a research presentation of a comparison analysis of spectroscopy data from using the constructed DIY spectroscope versus the commercially available apparatus: SpectroVis Plus with LoggerPro Analysis data.

For the first part, a spectroscope construction demonstration and workshop will take about 10-15 minutes. Materials such as upcycled cardboard or used coin bank, CD (disk), adhesives, etc. would be prepared and provided by the presenter so that session participants could experience the spectroscope construction.

The second part of the session would be a research presentation on how the DIY Spectroscope could be used in data analysis as compared to the data that was generated by a commercially available apparatus: SpectroVis Plus with LoggerPro Analysis data. LED, CFL, and incandescent light sources spectroscopy were observed using the DIY spectroscope and SpectroVis Plus light sensor analysis. Suggestions for how the DIY spectroscope could also be integrated in other Science topics in JHS (Biology and Chemistry) would also be presented.

Keywords: DIY spectroscope, SpectroVis Plus, LoggerPro, LED bulb, CFL bulb, incandescent light bulb

P18. AGENT-BASED SIMULATION OF SHOPPER INTERACTIONS AND MARKET FLOW IN BAYBAY CITY, LEYTE

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Public markets serve as vital economic and social hubs, yet their dynamic nature often presents challenges related to shopper flow, congestion, and vendor interactions. This study employs an agent-based modeling (ABM) approach to simulate shopper behavior within Baybay City's public market, aiming to analyze movement patterns and optimize market layouts. The model integrates key demographic factors such as age, gender, shopping purpose, and customer loyalty to replicate realistic shopper decision-making processes. Simulations reveal that shopper flow is influenced by stall arrangements, with congestion forming in high-demand areas such as fruit and vegetable sections. A proposed alternative market layout, redistributing these stalls, demonstrated improved shopper distribution and reduced congestion. Findings suggest that strategic stall placement can enhance market efficiency, benefiting both vendors and shoppers. This study contributes to the understanding of market dynamics in developing regions and provides insights for urban planners and policymakers in optimizing public market operations.

Keywords: Agent-Based Model, Shopping behavior, public market layout

P19. PROJECT MANAGEMENT IN ACADEMIA: PRACTICAL STRATEGIES FOR STUDENTS, TEACHERS, AND ADMINISTRATORS

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Managing multiple projects especially in academia can be challenging: deadlines piling up, task responsibilities getting lost, unbalanced workload management. Whether you're a student, teacher, or an administrator, this workshop introduces practical, hands-on project management strategies to help you stay organized, meet project goals, and collaborate more effectively.

We'll look into key methodologies like Waterfall, Agile, Scrum, and Kanban and how they can be simplified and applied into academic projects. Through real-world examples, we'll break down tools like sprints, RACI charts, KPIs, and risk assessment matrices and how they can simplify your workflow and prevent common pitfalls like missed deadlines and scope creep.

The workshop includes hands-on activity using Asana (free version) where participants will learn to use it for study plans, lesson modules, research milestones, and event coordination. By the end of this workshop, participants will have set up their own project boards in Asana, created tasks, assigned deadlines, and organized their work using simplified project management techniques to help stay organized and work more efficiently.

P20. EVALUATING THE ABSORBENCY AND CONTACT ANGLE OF ABACA (MUSA TEXTILIS) FIBERS TO VARIOUS LIQUIDS

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Abaca (Musa textilis) fibers are used in various industries and are known for their mechanical strength and hydrophilic properties. In this study, the contact angle of different liquids (tap water, saltwater solution, and cooking oil) on varying strands of abaca fibers was measured. Four bundles (with 20, 40, 60, and 80 numbers of strands) of abaca fibers, were twisted 20 times. Three trials of the different liquid were dropped on the four bundles twisted abaca strands. The contact angle was measured using Image J application with the Low Bond Axisymmetric Drop Shape Analysis (LBADSA) plug-in. The absorption time was also measured. The results indicate that abaca fibers exhibit the highest resistance to saltwater, with longest absorption times up to 13 minutes for 80 strands and relatively stable contact angles which is ~83°, suggesting a degree of hydrophobicity in saline environments. In contrast, tap water absorption times were the shortest and higher contact angles, while oil exhibited the lowest contact angles and faster absorption rates. The tap water and cooking oil set-up showed inconsistency with both the contact angle measurement and the absorption time. It can be concluded that abaca fibers can be resistant to saltwater solution, and that the greater the number of strands is in a twisted bundle, the greater is the absorption time. These findings highlight abaca fibers' potential applications in moisture-resistant materials, particularly in saltwater-exposed environments.

Keywords: Abaca fibers, Contact Angle measurement, Absorption

P21. EXPLORING THE BRACHISTOCHRONE CURVE: A WORKSHEET AND LOW-COST SETUP ON CLASSICAL MECHANICS AND OPTIMIZATION

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The principle of least action is a fundamental concept in Classical Mechanics, yet it is often overlooked in traditional classroom instruction despite its prevalence in the natural world. This study designed and constructed an experimental setup using low-cost materials to demonstrate this principle through the brachistochrone curve. The setup was developed using the Successive Approximation Model (SAM) to ensure iterative refinement and effectiveness. Additionally, a

worksheet based on Gagné's Nine Events of Instruction was created to guide students through the experiment and its analysis. The initial results indicate that the setup successfully provides a hands-on, cost-effective, and pedagogically sound tool that enhances students' conceptual understanding of the principle of least action by offering a tangible and visual representation of its application.

Keywords: Principle of least action, Successive Approximation Model, Brachistochrone curve, Gagne's Nine Events of Instruction

P22. AGENT BASED MODEL OF BACTERIA GROWTH AND NUTRITION

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Agent-based models (ABMs) are powerful tools for describing and simulating real-world systems. ABMs employ a rule-based computational approach that emphasizes the interactions and behaviors of individual components within a system. In this study, ABM was used to model bacterial growth across varying nutritional environments. Bacterial reproduction is assumed to be asexual, mirroring fission: a single bacterium divides into two, with the parent bacterium dying in the process. The algorithm checks for available space in the environment before generating a new bacterium and also takes into account the movement of bacteria to their nearest 8, 24, or 48 neighbors. Probability conditions are applied to the likelihood of occupancy within these neighborhoods. Additionally, the availability of nutrients is monitored prior to cell division. The model does not incorporate specific mechanisms of bacterial motility. The ABM was implemented using Python, and to validate its ability to replicate realistic bacterial behavior, simulations of bacterial nutrient dynamics were conducted. The simulations modeled a closed habitat, where all resources are finite and non-renewable, and where metabolites from living cells, as well as deceased cells, are not removed. The results from these simulations showed a bacterial growth curve that included distinct phases: lag, exponential growth, stationary, and mortality/death phases. These phases closely resemble the typical growth behavior of bacteria in a closed environment, as documented in the literature.

Keywords: Agent based Model, Bacteria growth, bacteria nutrition

P23. PHOTON THERAPY DOSE CALCULATIONS IN PEDIATRIC PHANTOM WITH HEAD AND NECK TUMOR

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Cancer remains one of the leading causes of death among children and adolescents, with head and neck cancer (HNC) accounting for 2-15% of all pediatric cancer cases. Along with surgery and chemotherapy, radiation therapy is a key treatment option for pediatric HNC. However, dose limits must be established to minimize toxicity due to the sensitivity of a child's developing organs. An international research collaboration is needed to account for variations in the anatomical and physiological traits of pediatric patients. This study aims to calculate absorbed doses and visualize the particle spectrum in a 10-year-old pediatric phantom. The phantom was developed using data from the IAEA Reference Asian Man, specific to Filipino children. The phantom construction and absorbed dose calculation were done using the Monte Carlo Particle and Heavy Ion Transport Code System (PHITS) version 3.250. A 6-MeV photon source, modeled from a 6-MV Varian linac, was collimated and directed toward the tumor volume. Simulation results show that the tumor received the highest absorbed dose of $1.67 \times 10^{-13} \pm 0.15\%$ Gy/photon, accounting for approximately 90% of the total dose in the head and neck regions. Meanwhile, the soft tissue absorbed 3.97% ($7.36 \times 10^{-15} \pm 0.07\%$ Gy/photon), followed by the brain at 2.16% ($1.08 \times 10^{-16} \pm 0.23\%$) and lastly the skull at 0.91% ($1.41 \times 10^{-16} \pm 0.24\%$). The absorbed dose distribution obtained in this study, using a pediatric phantom designed with Filipino data, could help establish dose recommendations for photon therapy in pediatric patients.

P24. CONDUCTANCE ANALYSIS ON THE CONDUCTIVE PROPERTY OF STEEL-WOOL, METALLIZED CELLOPHANE WRAPPER, AND MEDICINE BLISTER FOIL

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Conductivity measurements are essential in research and development, allowing scientists to understand material behaviors, optimize processes, and improve the design of electronic components and devices. This study explores the electrical conductivity of three distinct waste materials—steel wool, metallized cellophane wrappers, and medicine blister foil—assessing their potential as thin-film conductive materials. The materials were processed into pieces smaller than 1 mm. Three experimental setups were designed, each with varying ratios of the materials to a non-conductive adhesive. The conductivity of the samples was measured using the four-point probe technique. For each setup, three replicates were tested, with conductivity measurements taken five times for each replicate to ensure reliability and accuracy. The experimental findings of the varied samples resulted in a significant difference of the conductivity. For the steel-wool, the resistivity decreased as the portion of conductive material is increased which implies an improved conductivity in the composite material. Correspondingly, the metallized cellophane wrapper displayed a general increase in conductivity as the ratio of shredded material was increased. On the other hand, the medicine blister foil exhibited a minimal to no current which is likely due to factors such as the insulating plastic coating. These findings demonstrated possible waste material selection for conductive thin film applications while identifying critical factors influencing its performance.

P25. BEYOND THE PRESENT NUCLEAR LANDSCAPE

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Explorations beyond the current limits of the nuclear landscape have been an active area of research in both theoretical and experimental atomic and nuclear physics. On the theoretical side, various nuclear models are available to simulate several nuclear properties and provide predictions for the uncharted territories of the existing chart. On the experimental side, numerous laboratories around the world are dedicated to synthesizing new elements and isotopes despite the challenging "atom-at-a-time" discovery process. This talk will present a review of the essential concepts necessary for understanding the atomic nucleus and its properties. A particular energy density functional, the Quark-Meson Coupling (QMC) model, will also be introduced, which has demonstrated excellent predictive power in calculating several ground-state observables of all finite nuclei with an even number of protons and neutrons1,2,3,4. QMC model predictions were extended to regions of the nuclear chart where no experimental data is currently available. These results are crucial in understanding the evolution of nuclear structure and mechanisms, transitioning from lighter species toward the superheavy region.

P26. UTILIZATION OF TRACKER SOFTWARE IN PHYSICS EXPERIMENTS

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Physics involves various experiments that correlate to different theories. One of the challenges in conducting experiments is to minimize the error. In this study, the Tracker software was utilized in physics experiments that required precision and accuracy in data collection. Tracker is a free video analysis and modeling tool built on the Open Source Physics (OSP) Java Framework. It is used to combine videos with computer modeling. The physics experiments that were focused in this study were uniformly accelerated motion that involved free-falling objects, and the motion of simple pendulum and a double pendulum. The utilization of Tracker software in physics experiments has significantly enhanced the analysis and visualization of motion-related phenomena. The ability of the software to integrate dynamic modeling, graph plotting, and data exportation provides a comprehensive platform for conducting experimental analysis with minimal equipment. The findings suggest that incorporating Tracker into physics experiments can significantly enhance experimental accuracy and foster a deeper understanding of physical principles.

Keywords: Tracker software, Uniformly Accelerated Motion, Simple Pendulum, Double Pendulum

P27. CONTACT ANGLE MEASUREMENT OF PULVERIZED GUAVA (PSIDIUM GUAJAVA) SEEDS

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Guava seeds possess natural antimicrobial properties. Building on this, we explored whether guava seeds could serve as an effective surface coating. To examine changes on the seed's surface properties, we processed the guava seeds by pulverizing and baking them at different durations. Our tests revealed that guava seeds are hydrophilic, making them an ideal substrate for coating applications due to their excellent wettability and antimicrobial qualities. However, once the seeds are completely burnt, they exhibit hydrophobicity. Additionally, no significant difference

in contact angles was observed across varying baking durations, as long as the seeds remained within a certain threshold.

Keywords: Seeds, Contact Angle, Anti-microbial

P28. CONTACT ANGLE MEASUREMENT: EXPLORING DROPLET ABSORPTION ON CHARCOAL SURFACE TEXTURE VARIATIONS

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The experimental study observes the behavior of water droplet absorption across charcoal materials of different particle sizes and textures. Its importance involves determination of hydrophilic or hydrophobic properties of charcoal produced from coconut wood and shell. Such study is performed using the ImageJ application program and videography to collect data on contact angle measurement. Based on the numerical data for contact angles, the study shows that the hydrophobic properties of pounded charcoal are noticeable when the particle size is less than 0.75 millimeters after sifting, where the contact angle detected is significantly higher.

Keywords: contact angle, charcoal, hydrophobicity/hydrophilicity, water absorption

P29. UV-VIS SPECTROSCOPY OF BELL PEPPER (CAPSICUM ANNUUM) WITH VARYING PIGMENT

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Pigments in plants, such as chlorophylls, carotenoids, flavonoids, anthocyanins and betalains play an important role in human health. This study utilized fresh bell peppers of four different pigments (green, red, red-orange, and orange). Pure extracts of the bell peppers were obtained. Distilled water was added to separate samples of the pure extracts to assess the effects of dilution. Both pure and diluted samples were transferred into glass cuvettes and subjected to a UV-Vis spectrometer. The absorbance and transmittance values were measured at specific wavelengths corresponding to the maximum absorption peaks. Different wavelength characteristic was

prominent for the green, red, red-orange and orange bell pepper extracts. Moreover, the absorbance decreases while transmittance increases with dilution, consistent with the Beer-Lambert Law. This research provides precise wavelength and absorption values for various bell pepper pigments and their dilutions, offering a more reliable method for color characterization thn visual inspection, which can be highly inconsistent depending on the observer.

Keywords: UV-Vis Spectroscopy, Pigment Behavior, Bell Peppers, Absorbance, Transmittance, Food Science

P30. QUANTUM MECHANICS FOR ADMU PHYSICS MAJORS

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This paper seeks to share our experience of introducing the first principles of Quantum Mechanics to students majoring in physics at the Ateneo de Manila University, encourage students to study advanced physics and mathematics and understand their contributions to modern society. The basic principles of quantum physics are explained and illustrated with examples of problems limited to the one-dimensional case and normalizable wave functions and solved using differential and integral calculus and simple differential equations. It has been shown that electrons and photons possess both particle and wave natures. The quantum description mixes the particle and wave natures and can only provide an approximate location of dimension Δx and has Δp corresponding to a range of de Broglie waves. Quantum mechanics therefore uses the language of probabilities and statistical averages or expectation values. Two fundamental systems arise in quantum mechanics—the *infinite square well* and the *quantum harmonic oscillator*. The infinite square well provides insight into quantized energy levels and wave functions arising from boundary conditions that confine a particle within rigid walls. Meanwhile, the quantum harmonic oscillator is a mathematical model describing the behavior of a system in a potential behaving like a spring. The ground and excited states of the harmonicoscillator are further examined by solving the time-independent Schrödinger equation using the *ladder operators*. Finally, this paper discusses how we describe real and observable systems using the mathematical tools of Quantum Mechanics: wave functions and operators. We show how wave functions that live in Hilbert Space, or square-integrable functions, describe real systems. We also explore how different observable measurements are obtained using Hermitian Operators. Lastly, basic mathematical properties of square-integrable functions and Hermitian Operators are also discussed.

P31. SUSTAINABLE ENERGY: A BREAKTHROUGH PROTOTYPE OF KINETIC- POWERED CHARGING STATION

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Aim/Background: The study investigates the potential of a kinetic energy-powered charging station as a sustainable energy solution, utilizing piezoelectric technology to convert kinetic energy from human footsteps and two-wheeled vehicles into electrical power. The research highlights the growing need for renewable energy solutions in rural environments with high foot traffic. The primary objectives are to evaluate the energy generated from movement, assess the effectiveness of conversion and storage, and analyze the impact of usage frequency on system performance.
Material and Methods: A quasi experimental design was used to develop, construct, and test the prototype in a controlled setting, measuring its performance under varying conditions.
Results: The results show kinetic energy calculations revealed that a human weighing 70 kg and walking at 1.4 m/s generated 68.6 joules, while a motorcycle weighing 180 kg at 15 m/s produced 20,250 joules. A steady increase in voltage with extended use: 1.44 volts over 24 hours, 5.76 volts over 96 hours, and 10.08 volts over 168 hours. The prototype's effectiveness was evaluated on a scale from 1 (outstanding) to 5 (needs improvement), demonstrating high efficiency under optimal conditions but reduced performance with low activity levels.
Conclusion: The findings indicate that the prototype performs reliably in hightraffic areas, supporting its viability for long-term energy generation. Recommendations include enhancing platform sensitivity for lighter inputs, reinforcing durability for heavier impacts, and conducting further trials across diverse settings. The research suggests that the kinetic energy-powered charging station could contribute to sustainable energy goals by reducing reliance on nonrenewable sources.

Keywords: Kinetic energy, Piezoelectric technology, Sustainable energy, Renewable power

P32. AN AGENT-BASED MODEL SIMULATION OF PURCHASE DECISIONS OF ONLINE CONSUMER BEHAVIOR

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This study simulates online consumer purchasing behavior using an agent-based model to explore how risk aversion, budget sensitivity, brand loyalty, and review sensitivity influence purchase decisions. By creating agents with varied profiles to evaluate products with distinct attributes (e.g., score, price, and sentiment), the model reveals that review-sensitive, low-budget-sensitivity agents favor highly-rated products, while brand-loyal agents prioritize items from preferred brands. These findings highlight the importance of personalized marketing in e-commerce and suggest that future research could incorporate dynamic consumer preferences and peer influence to further refine understanding of online decision-making.

Keywords: Agent based models, Online consumer behaivor, Purchase decisions, risk aversion, Budget Sensitivity, Brand Loyalty, Product Reviews

P33. MATHEMATICAL PHANTOM DESIGN FOR RADIATION THERAPY DOSE CALCULATIONS USING PARTICLE HEAVY ION TRANSPORT CODE SYSTEM (PHITS)

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Radiation oncology research often faces challenges in patient recruitment due to the risks associated with ionizing radiation exposure. Ensuring fully informed consent and implementing safety measures are critical but can limit study feasibility. To address these challenges, computational phantoms provide a low-risk alternative by digitally modeling the human body for radiation dose calculations, treatment planning, and radiological research. These phantoms eliminate direct patient exposure while allowing for widespread use in computational simulations. Among them, mathematical phantoms—constructed from simple mathematical expressions—offer computational efficiency and ease of modification, albeit with reduced anatomical accuracy. Despite their simplified structure, these phantoms can provide reliable dose estimations for radiation studies. Currently, there is no available phantom made with adult Filipino-specific anthropometric data. To fill this gap, this study aims to design an adult Filipino male mathematical phantom with the use of the Particle and Heavy Ion Transport code System (PHITS) version 3.34, developed by the Japan Atomic Energy Agency. The phantom is composed of basic geometric shapes, including spheres, ellipsoids, and cylinders, to represent the cerebrum, cerebellum, brainstem, heart, liver, lungs, testes, spine, ribs, arms, and legs. Tissue density and chemical composition data used were from ICRU report 46 and ICRP publication 89. Anthropometric data and organ masses were taken from the IAEA Reference Asian Man Vol.2. The developed phantom aids in an ongoing study onproton beam therapy Monte Carlo simulation using PHITS ver. 3.34 and may serve as a foundation for future research and improvements.

P34. CLASSIFICATION OF AGRICULTURAL LAND USING OPTICAL SATELLITE DATA AND MACHINE LEARNING

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The Philippines imports more agricultural products than it exports, despite having fertile lands, and one in ten households faces food insecurity. This research integrates optical satellite data and machine learning to classify land with agricultural potential, addressing the need for efficient land-use identification. Using Landsat-8 spectral bands (B4, B3, B2) and the CORINE dataset, a pixel classifier was developed employing four algorithms: Random Forest, CART, Naïve Bayes, and Support Vector Machines (SVM). Results showed that Naïve Bayes excelled in identifying artificial structures but struggled with water classification, while CART emerged as the most accurate algorithm. However, the European-based CORINE dataset caused inaccuracies in Philippine data, underscoring the need for localized datasets. This study demonstrates the potential of machine learning and satellite data for agricultural land classification and highlights the importance of localized training data to improve model accuracy.

Keywords: Remote sensing, satellite data, machine learning, agriculture land classification

P35. ADSORPTIONS OF HYDROGEN ON THE DIFFERENT SURFACES OF COMMON CATALYTIC METALS USING FIRST-PRINCIPLES DENSITY FUNCTIONAL THEORY CALCULATIONS

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This study explores the adsorptions of hydrogen molecules on the surface of the common catalytic metals such as cobalt, gold, and nickel with 1 mL adsorbate coverage. The research employs Density Functional Theory (DFT) calculations based on Quantum Espresso to determine the most stable bulk structures and their corresponding surface energies. Density Functional Theory (DFT) is one of the most common methods used for "first-principles" calculations of the crystals, structure of atoms, surfaces, and their energy interaction. Understanding these properties is essential for enhancing the efficiency of these metals in different applications. The results shows that the face-centered cubic are the most stable structure for the metals studied. Additionally, the

(111) surface of nickel, the (211) surface of gold, and the (110) surface of cobalt are the most suitable adsorbents among the different metal surfaces.

Keywords: adsorption energy, Density Functional Theory, Quantum Espresso, surfaces

P36. THE TRANSLATIONAL AND ROTATIONAL MOTION OF MULTIPLE BOUNCING BALLS ON VIBRATING FLUID BATH: A SMOOTHED PARTICLE HYDRODYNAMICS SIMULATION

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Over the years, the phenomenon of "walking droplets" and bouncing balls on vibration-energized surfaces has drawn widespread attention due to the wealth of complex behaviors and its possible analogy with quantum mechanical behavior. And it has been discovered that the smoothed particle hydrodynamics (SPH) method is effective in simulating droplets walking on viscous vibrating liquid. Furthermore, only a few studies have been conducted on multiple-ball systems, compared to a single bouncing ball.

We used FreeCAD v.0.19, specifically the DualSPHysics, a powerful SPH Navier-Stokes solver designed for simulating multiphysics phenomena, to perform 3D numerical simulations of a vibrating sphere-fluid system in order to examine the translational and rotational motions of multiple bouncing balls. Within a cylinder (thickness = 10 mm, inner radius = 150 mm, inner height = 290 mm), each ball is set up as a floating body (mass = 2.7 g, radius = 20 mm) that is initially completely submerged in a fluid (height= 40 mm, density = 1 g/cm^3). The cylinder, on the other hand, is configured as a moving solid with a sinusoidal vibration of fixed frequency (40 Hz) and fixed amplitude (0.001 m) along the vertical z-axis. To visualize the simulated data, we utilized Paraview v.5.9.1, which can also deduce some potential reasons for the variations in the translational and rotational dynamics of the multiple balls. Based on our simulations' results, there are differences in the time evolution of the translational (v_x, v_y, v_z) and rotational $(\omega_x, \omega_y, \omega_z)$ velocity magnitudes of the bouncing ball/s that were examined.

Keywords: smoothed particle hydrodynamics, numerical simulation, complex system, cooperation

P37. EXTRACTION AND MOISTURE CONTENT DETERMINATION OF STARCH FROM CASSAVA (MANIHOT ESCULENTA) PEELS

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Cassava peel is considered an agricultural waste and often ignored, but it is abundant and renewable. This study extracted starch from cassava peels to maximize its utilization and help reduce environmental pollution. Here, cassava peel starch was extracted through wet milling and dried using the oven-drying method. Our results revealed that the percent yield of cassava starch is 13.0%, and its moisture content is 74.2%. The findings of our study indicate that this crop waste by-product can be a valuable starch alternative for various food and non-food applications.

Keywords: Cassava, cassava peel, starch, percent yield, moisture content

P38. HEALTH HAZARDS EXPOSURE AND HEALTH QUALITY OF RADIOLOGY DEPARTMENT PERSONNEL IN NEGROS ORIENTAL

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Medical Radiation workers` daily exposure to radiation could result in the late effect radiation injury. They are also very susceptible to different communicable diseases. Factors contributing to their occupational conditions have to be appropriately addressed, such as to formulate administrative policies and programs on occupational health. This study aimed to determine the health hazards exposure of the radiology department personnel in the health facilities of Negros Oriental, and how these affect the quality of their health. The study included 56 participants working in the free-standing and hospital radiology departments in Negros Oriental. The majority were males, young professionals, and who had been working in radiology for less than 10 years. The study showed that there is no significant correlation between age, sex, length of service, length of radiation dose, stress factors, work environment, and health hazard exposure among the medical radiologists in Negros Oriental, except for alcoholic drinking.

P39. USING THE MOVING MAN PHET SIMULATION TO TEACH UNIFORM VELOCITY THROUGH DISTANCE-TIME GRAPHS IN GRADE 7

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Understanding uniform velocity and distance-time graphs can be challenging for Grade 7 students. This presentation focuses on using the Moving Man PhET simulation as an interactive tool to enhance conceptual understanding. It is aligned with one competency in the Third Quarter Matatag Curriculum for Science 7: Describe uniform velocity and represent it using distance-time graphs.

The simulation offers an effective visualization of motion, allowing students to manipulate position, velocity, and time while interpreting position-time graphs. Through guided inquiry-based

activities, students predict, analyze, and refine their conceptual understanding of kinematic concepts like distance, displacement, speed, and velocity.

This session highlights the integration of the PhET simulation into lessons, addressing common student difficulties and demonstrating strategies to foster scientific conception of kinematics concepts through guided activities.

Keywords: Uniform Velocity, Distance-Time Graphs, PhET Simulation, Inquiry-Based Learning, Physics Education

P40. PHYSICO-CHEMICAL PARAMETERS OF THE LIMNETIC AND LITTORAL ZONES OF LAKE PINAMALOY, DON CARLOS, BUKIDNON

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Lake Pinamaloy, a vital freshwater resource in Bukidnon, Philippines, serves as a primary site for fishing and a crucial water source for the local community. This study, conducted in situ, aimed to assess spatial variations in key physico-chemical parameters across five sampling stations in the limnetic and littoral zones, measuring temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity. Results revealed significant differences in temperature ($p < 0.0001$), turbidity ($p = 0.000328$), and salinity ($p = 0.034559$), suggesting environmental influences on water quality. Turbidity levels (20.08 NTU mean) exceeded the <5 NTU threshold, indicating high levels of suspended particles that may affect fish populations and aquatic ecosystem health. Other parameters, including pH (6.78), EC (61.13 µS/cm), TDS (29.6 mg/L), and salinity (30.33 mg/L), remained within acceptable limits. These findings provide essential baseline data for water quality monitoring and underscore the need for pollution control measures. Future studies should investigate seasonal variations and potential pollution sources to develop effective conservation strategies.

Keywords: freshwater ecosystem, Lake Pinamaloy, physicochemical parameters, water quality

P41. DESIGN AND DEVELOPMENT OF A GREENHOUSE SOLAR CORN DRYER FOR THE FARMERS OF CABANGLASAN, BUKIDNON

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In this study, a hybrid greenhouse solar dryer (GSD) was partially created, and one trial was conducted to collect preliminary data and evaluate strengths and weaknesses in the design. To specify, this was done to create an innovation in drying techniques, as many agricultural areas in the Philippines still utilize the traditional drying method, open sun drying (OSD). Six (6) sacks of DEKALB corn were purchased, split into halves, and dried through two (2) drying methods: the developed design and the open sun drying process (OSD). The essential parameters that were collected involved the moisture content, cost, and drying process time. Results from one (1) trial of drying corn showed how the GSD design, without the heating system and solar fans, turned on due to needing further development, dried less total moisture compared to the OSD, with the ending mean moisture of the former being 16.0%, while the latter had 15.5%. The analysis of data using the Wilcoxon Test showed no significant differences between the efficiency of the GSD and the OSD. Yet, this conclusion was impacted by the small sample size. Therefore, the GSD requires further enhancements, trials, and sample sizes to dry corn faster than the OSD and comprehensively assess the comparison of performances.

Keywords: Greenhouse Solar Dryer (GSD), Open sun drying (OSD), corn, drying process, moisture content, cost, time

P42. RESOLUTION OF FORCES: THE COSINE LAW

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This presentation explores the resolution of forces using the Cosine Law through a hands-on demonstration. Utilizing a set of plastic bottles and a self-made Cosine Law apparatus, we will experimentally determine the resultant force using the Cosine law formula.

The experimentally obtained resultant will then be compared with results derived through the polygon method and the theoretical calculation using the Cosine Law. This comparative approach highlights the accuracy and practical application of vector resolution techniques in physics.

P43. INTEGRATING ENVIRONMENTAL LITERACY IN PHYSICS BASIC EDUCATION: A BLOOM'S TAXONOMY-BASED FRAMEWORK

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One of the key outcomes of the Philippine K to 12 science curriculum is to develop environmental literacy among learners. However, both in literature and in practice, there is a noticeable gap in utilizing physics education as a means to achieve this goal. This study presents a Bloom's Taxonomy-based framework for integrating environmental literacy into physics basic education, aligning cognitive learning processes with sustainability principles. The framework progresses from Remembering fundamental physics concepts (e.g., laws of motion, energy conservation) to Creating innovative solutions for real-world environmental issues (e.g., renewable energy systems, climate change mitigation strategies). Each cognitive level is linked to key environmental applications, enabling students to analyze, evaluate, and design physics-based solutions to ecological problems. This study employs a Design and Development Research (DDR) approach, utilizing autoethnographic reflections and a comprehensive literature review as the foundation for framework construction. By drawing from first-hand teaching experiences, challenges, and successes in integrating sustainability into physics education, this research provides an insider perspective on effective instructional strategies. Additionally, a systematic review of curricular standards, environmental education policies, and best practices in physics instruction informs the framework's theoretical grounding. The study highlights teaching strategies, lesson applications, and assessment methods that support educators in embedding sustainability concepts into physics instruction. Ultimately, this framework serves as a pedagogical tool that bridges physics education and environmental advocacy, fostering scientific awareness and responsible citizenship among students.

Keywords: Environmental Literacy, Physics Education, Bloom's Taxonomy, Philippine K to 12 Science Curriculum

P44. COMBATING MISCONCEPTIONS ON PROJECTILE MOTION THROUGH SCIENCE COMMUNICATION STRATEGIES

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This study aimed to explore the effectiveness of science communication strategies — GIFs/memes, storytelling, creative metaphors, and short evidence-based videos — in addressing scientific misconceptions, specifically Physics among science learners. As misconceptions hinder students' understanding of key scientific concepts, a creative reinforcement is essential. A mixed-method research design was used in which common themes on students' behaviors and interactions

were taken from observationsheets adapted from the 2011 University of Texas System/ Texas Education Agency andrecorded scores from assessments to provide a supportive role to the qualitative data. The study involved Grade 9 students and were divided into experimental and control groups, with the former exposed to interventions using science communication strategies while the latter received traditional instruction. Qualitative data from observation sheets and quantitative analysis revealed that students in the experimental group demonstrated a better understanding of scientific concepts, as evidenced byhigher mean scores in Physics assessments. These findings highlight the potential of science communication strategies in enhancing science education and effective in addressing persistent science misconceptions.

Keywords: science communication strategies, combating misconceptions, projectile, GIF/memes, storytelling, creative metaphors, short evidence-based videos, Physics

P45. CONTEXTUAL TEACHING AND LEARNING IN PHYSICS: DEVELOPING AN INSTRUCTIONAL MATERIAL TO ADDRESS STUDENTS' MISCONCEPTIONS ON NEWTON'S LAWS OF MOTION

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This study aimed to develop an instructional material on Newton's Laws of Motion using Contextual Teaching and Learning (CTL) and examine its impact on students' conceptual understanding. Traditional physics instruction often overlooks students' deeply rooted misconceptions, leading to fragmented learning. A mixed methods research design was employed, identifying misconceptions such as impetus dissipation, force-mass misconceptions, and confusion between velocity and acceleration from the literature. The instructional material was designed to address these issues through inquiry-based activities and real-world applications. It was implemented in a senior high school Physical Science class with students of varying scientific reasoning levels. Quantitative data from a conceptual inventory complemented qualitative insights from focus group discussions, activity sheets, and student reflections. Results showed significant learning gains, with the material proving effective regardless of students' scientific reasoning levels. These findings emphasize the potential of CTL-driven instructional approaches to promote conceptual understanding and meaningful learning (Crawford, 2001).

Keywords: Contextual Teaching and Learning, instructional material, scientific reasoning, misconceptions, conceptual understanding, Newton's Laws of Motion, physics education

P46. UTILIZING GAME-BASED TEACHING IN PHYSICS FOR NON-STEM STUDENTS

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Game-based teaching is acknowledged as an effective pedagogical approach that enhances student engagement. It also fosters active learning, improves the understanding of scientific concepts, and develops 21st-century skills (Qian & Clark, 2016). This presentation will explore various game-based teaching strategies designed to creatively introduce fundamental physics concepts to non-STEM students, who often have diverse cognitive backgrounds and little to no prior exposure to physics and related sciences. During the short talk, different games will be presented along with their learning objectives, goals, game elements, and feedback mechanisms. A game-based teaching strategy, grounded in both theory and practical experience, has been shown to increase student confidence, enthusiasm, and collaboration skills. The use of games in physics lessons has significantly boosted student participation, making abstract physics principles more accessible and enjoyable. In summary, incorporating games into physics instruction for non-STEM students is an innovative approach that enhances their appreciation of the subject, particularly for those who may struggle with traditional instructional methods.

Keywords: Game-based teaching, Physics education, non-STEM students, Student, engagement, Active learning.

P47. UNRAVELING MISCONCEPTIONS IN PHYSICS: A LITERATURE REVIEW ON COMMON ALTERNATIVE CONCEPTIONS

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This literature review examines the common misconceptions or alternative conceptions that non-STEM students often struggle with physics. Misconceptions in physics frequently result from everyday experiences, instinctive judgement, and simplistic comparisons (Kotsis, 2023). Due to these, misconceptions such as gravity is absent in space, planets move in perfect circles, and heavier objects are harder to push solely due to weight would arise. Some students often confuse displacement with the total distance traveled. These misunderstandings contribute to the perception of physics as difficult and abstract. To improve comprehension and address common misconceptions, educators should use inquiry-based learning, real-life applications, and interactive teaching methods. Addressing these alternative conceptions is crucial for enhancing non-STEM students' engagement, scientific literacy, and appreciation of physics in daily life.

Keywords: Misconceptions, Alternative Conceptions, Physics Education, Non-STEM Students, Scientific Literacy, Conceptual Change, Inquiry-Based Learning

P48. BRINGING OPTICS TO LIFE: TEACHING LENS PRINCIPLES THROUGH INTERACTIVE DIY EXPERIMENTS

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Teaching the principles of lenses and image formation through DIY materials provides an engaging and cost-effective approach to understanding optical physics. This study presents a hands-on approach to teaching lenses and image formation using DIY materials. By utilizing simple items like water droplets, plastic bottle lenses, gelatin molds, and magnifying glasses, we can effectively demonstrate how convex and concave lenses manipulate light to create images of different sizes, orientations, and types. For instance, a water droplet on plastic wrap acts as a convex lens, converging light to form magnified virtual images, while a concave gelatin mold illustrates the diverging effect of concave lenses. A pinhole camera experiment using a shoebox and a convex lens offers a practical representation of image formation in cameras and the human eye. These activities connect theoretical concepts to real-world applications, making optics more relatable for students.

By integrating mathematical analysis, this study applies the **lens formula**

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

to predict and verify image formation based on object distance and focal length. The experiments also highlight the practical significance of lenses in everyday technologies such as **eyeglasses, microscopes, and telescopes**. It emphasizes the importance of **active learning** in physics education, offering simple yet effective methods for students to explore fundamental optics concepts through DIY experimentation. By engaging participants in hands-on demonstrations, this study enhances conceptual understanding and encourages deeper inquiry into the physics of light and lenses.

P49. VISUALIZING INVISIBLE FORCES: DIY FERROFLUID EXPERIMENT AS A TOOL FOR UNDERSTANDING MAGNETISM AND FLUID BEHAVIOR

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Ferrofluids are nanoscale magnetic particles suspended in a carrier liquid, exhibiting unique behaviors in external magnetic fields. This study analyzes the dynamics of these particles, showing how ferrofluids switch between fluid-like and solid-like states based on varying magnetic forces. The experiment involves mixing iron oxide powder with oil to create a magnetic fluid that reveals magnetic field lines visually. The resulting spike-like structures formed by magnetic domain

alignment and fluid surface tension allow direct observation of magnetic attraction, particle suspension, and fluid dynamics.

To understand the forces acting on ferrofluids, we use the magnetic force equation: $F=\nabla(m\cdot B)$, where F is the magnetic force, m is the magnetic moment of the particles, and B is the magnetic field strength. This equation highlights that the motion of ferrofluids is influenced by the magnetic field's spatial variation.

By adjusting the position and strength of an external magnet, we demonstrate how viscosity, surface interactions, and magnetic forces affect ferrofluid motion and stability. This has practical applications in engineering, medicine, and materials science, including uses in magnetic seals, targeted drug delivery, and adaptive optics. The DIY ferrofluid experiment serves as an accessible educational tool, simplifying complex magnetic concepts for students and researchers. It emphasizes the significance and applications of ferrofluids, showcasing their role in exploring the relationship between magnetism and fluid mechanics.

P50. DEMONSTRATIONS, PHENOMENA, AND FUN WITH PLANE MIRRORS

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With a set of plane mirrors, the following will be discussed/shown/demonstrated: Law of Reflection; Image Formation in Plane Mirrors; Truth Mirror; Infinity Tunnel; Pentagonal Reflection; Periscope. (2 hrs)

P51. SOLAR-POWERED WATER PURIFICATION SYSTEM: INNOVATIONS IN PHOTOVOLTAIC FILTRATION TECHNOLOGIES UTILIZING BANANA (MUSA) PEEL-DERIVED ACTIVATED CARBON

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Access to clean drinking water remains a critical challenge in remote areas like Cabulohan, Cabanglasan, Bukidnon. This study aims to develop a solar-powered water purification system utilizing banana peel-derived activated carbon to improve water quality sustainably. The system harnesses photovoltaic (PV) energy to power a filtration process, integrating UV disinfection and activated carbon filtration to remove contaminants. Water samples were tested for turbidity and pH

levels before and after purification. Results demonstrated a significant improvement in water quality. Purified water showed a low turbidity level of 0.37 NTU, well below the DENR standard of 1 NTU, compared to untreated river water, which had an average of 6.5 NTU. The pH of purified water was 7.64, within safe drinking limits, while untreated water had an alkaline pH of 9.38. This study highlights the potential of integrating solar energy with sustainable filtration methods to provide safe drinking water in underserved areas. This would offer an eco-friendly and cost-effective alternative to traditional water purification methods.

Keywords: filtration, photovoltaic, solar, turbidity, water quality

P52. HANDS-ON LEARNING WITH ROBOTICS: ARDUINO AND EV3

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Arduino and EV3 LEGO are powerful platforms for learning robotics and programming. Arduino, an open-source microcontroller, enables users to build automated systems, while EV3 LEGO offers a programmable robotics kit with smart motors and sensors. To demonstrate their applications, two hands-on activities will be conducted: the Arduino Line-Following Robot, which uses sensors to detect and follow a path, and the EV3 Sumo Robot, where programmed robots compete to push each other out of a ring. These demonstrations will enhance students' problem-solving, coding, and engineering skills, making Arduino and EV3 valuable tools for STEM education.

P53. ACCEPTABILITY OF EINSTEIN SHAPE AND CORN COB ASH AGGREGATE AS MODIFICATIONS IN THE MAKING OF A CONCRETE PAVER BRICK

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The Einstein shape is a craggy, hat-like shape that is said to cover any flat surface perfectly, forming an aperiodic pattern. This paper aims to determine the acceptability of the Einstein shape as a modification to the shape of a paver concrete brick along with corn cob ash aggregates, which stabilize and strengthen concrete bricks. It utilized an experimental research design wherein the researchers compared which among their samples were the most ideal according to their compressive strength, water absorption and visual appeal.

The researchers created twelve (12) concrete bricks for testing. Three were cured for 7 days; 3 for 14 days; 3 for 21 days; and the last 3 were cured for 28 days. All four sets of samples of the distinct curing durations passed the standard specifications for a concrete paver brick in terms of compressive strength and water absorption (DPWH Item 741 - Interlocking Precast Concrete Blocks and ASTM C936/C936M), with the twenty-eight (28) days of curing time having the most ideal outcome. For the concrete brick's visua appeal, the respondents were fascinated by its unique figure, marketable potential, and memorable appearance.