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Lab-Tested: How Laboratory Design Affects The Performance of UST Chemical Engineering Students

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Abstract

This research centers on assessing and establishing the most optimal levels of environmental conditions within Chemical Engineering Laboratory 11 at the University of Santo Tomas. The assessment of the laboratory's lighting conditions, noise, and temperature levels aims to discern these independent variables' potential impacts or significance on students' titration experiment results in Chemical Engineering Laboratory 11. To conduct this analysis, Binary Logistic Regression, facilitated using IBM SPSS, was employed for computation and in-depth analysis of the results. The study's findings illuminate a positive correlation between laboratory conditions and students' experiment results. Hence, this research emphasizes the importance of how educational institutions should prioritize optimizing laboratory conditions as it highlights the crucial role of the physical learning environment in educational outcomes. This underscores the concept that the physical setting, particularly within educational contexts like laboratories, is more than just a backdrop— it serves as a significant participant in the learning journey. The study recommends further exploration and inventive strategies in designing and maintaining educational facilities. These facilities should not only fulfill essential functional needs but also actively enhance students' learning experience and well-being.

Keywords
Lighting Conditions, Noise Levels, Temperature, Titration Experiment Results, Laboratory

1. Introduction
Chemical Engineering is an engineering field that develops and designs manufacturing processes that deal with chemicals. Chemical Engineers develop processes in the laboratory that will then be used for practical application to produce commercial products (Chemical Engineering - American Chemical Society 2023). Generally speaking, the processes developed are designed to manufacture, modify, and transport materials through conducting experiments in the laboratory and then implementing the development in mass production. In workplaces like laboratories, proper workplace design is a crucial and essential component.

The ability of individuals to acquire knowledge can be significantly impacted by the condition of the indoor environment. Indoor Environmental Quality, which includes the lighting conditions, temperature, and noise level, can affect the learning and academic performance of students (Henk Willem Brink et al. 2020). The effectiveness of absorption and integration, the development of abilities, and the standard of activities such as reading can all be enhanced by the right indoor environmental quality settings. Devenish (2020) stated that good lighting can help increase cognitive performance in the psychological aspect. According to the Canadian Centre for Occupational Health and Safety (CCOHS)(2019), people gather and receive about 85% of information through their sense of sight. In making lighting designs in a workplace, the positioning of every lighting source for a specific use should be considered (Workplace Testing 2018).

From a worker's viewpoint, poor lighting quality can cause several disadvantages, from work errors to various health-related damages such as eye strain, headaches, nausea, and eye fatigue. A survey conducted by Lutron Electronics, which polled 1,001 office workers aged twenty-two (22) and above in the UK, focused on certain areas, including the impact of lighting on the mood and well-being of the workers. One of the key findings of the survey is that eighty-three percent (83%) of the respondents are frustrated by the lighting in their workplace. Another is that eighty percent (80%) of the respondents experience negative symptoms due to poor lighting. Within the office workers that have suffered negative effects due to poor lighting, forty-nine percent (49%) have experienced headaches. In comparison, forty-eight percent (48%) have experienced eye strain or eye irritation caused by lighting issues. (Bean 2017; Lutron 2017). Having the proper workplace design improves the workers' work experience by reducing the chances of occupational accidents and health problems caused by poor workplace design.

Determining if the current indoor environmental conditions of the laboratory are ideal for the Chemical Engineering students is essential to address emerging areas of concern when it comes to the working environment of students and their experimental outputs. This study will be beneficial to the Chemical Engineering students' ability to be more conducive in establishing efficient output while working in a laboratory in response to the lighting conditions, noise level, and temperature in their environment. With this study, the researchers will be able to distinguish if the students would be able to achieve the desired result or performance when it comes to the laboratory design while performing laboratory experiments and if it contributes to the student's ability to perform according to their best potential. This study would greatly contribute to the education industry. This would have an impact on the standards of classrooms and laboratories of the tertiary-level institutions in the Philippines and will further bring about an improvement to a more efficient studying environment.

1.1 Objectives

The main objective of the study is to determine and analyze the correlation between the illumination, noise level, and temperature of Chemical Engineering Laboratory 11 and the experiment results of UST Chemical Engineering students. The study aims to determine the effectiveness of the current indoor environmental conditions in the laboratory, how it can affect the success or failure in experimenting, and give improvements and recommendations accordingly. These objectives would then be achieved by:

1. Determining the effect of illumination level, noise level, and temperature level on the experiment results of the students in the University of Santo Tomas conducting Titration experiment at Chemical Engineering Laboratory 11.
2. Evaluating the correlation between current illumination, noise, and temperature of the laboratory and with experiment results by using statistical analysis.
3. Providing recommendations on optimum working conditions that would aid students in their academic pursuits.

2. Literature Review

In a study conducted by Mujan et al. (2019), it was stated that 87% of the time, people spend their time indoors in a residential or commercial building, while 6% is spent inside vehicles. This shows that people do spend more time indoors; hence, factors affecting indoor environmental quality (IEQ), which includes visual comfort, should be studied so people can be aware of the impact it has on health and efficiency. Artificial light, such as fluorescent and LED bulbs, is necessary in our day-to-day lives because it provides us illumination when natural light is not lacking. However, it also has its adverse effects. A study conducted by Katabaro & Yan (2019) in an office building in Tanzania showed the impact of lighting quality on the working efficiency of the workers. The results of the study identified that the employees were not satisfied with the lighting environment of their offices. Moreover, the quality of lighting in their offices was also insufficient as visual destructions like glare discomfort, lighting flicker, and sounds from defective circuits disturbed them, thus affecting their concentration. Such results of the study help raise awareness among institutions to ensure that suitable illumination is observed in their workplaces to avoid the effect on the performance and efficiency of an individual, their well-being, and their work satisfaction.

The diurnal light phase has a significant impact on the circadian timing for all organisms on Earth, according to Poddar & Guha (2021). Following the World Health Organization's (1994) Declaration on Occupational Health for All, which addressed the "Sick Building Syndrome" (SBS) of the 1970s, occupational health and architecture were combined. SBS is frequently defined as a collection of elements contributing to health issues linked to the built environment. This could lead to tension, worry, and subpar work performance. Their immediate environment can significantly impact a worker's performance. It has been demonstrated that a variety of significant both micro and macro elements of the environment have an impact on worker attitude. Scientific research has shown that the workplace has an impact on employee efficiency. The psychological effects also have an impact on a worker's imagination, state of mind, and the materials that make teaching and learning possible in the classroom. The researchers of the study examined and compared the academic achievement of senior high school students in Ghana depending on the physical environment of their school. The results of the study showed that students who work in a pleasant physical environment function better than those who do not have a satisfactory educational setting. Hence, the study of Baafi (2020) recommends that school administrators strive to ensure that the standard school design is followed and that the necessary resources are accessible in schools to foster excellent student performance in the classroom.

As for the context of temperature and background noise, ambient temperature is one of the factors that directly affect our performance at work. It affects not only efficiency but also the social and behavioral aspects in a workplace, which explains that the overall thermal comfort of a person impacts mood, efficiency, and even lifestyle (Business Minded, 2021). While in open-plan study environments, background noise can disturb students' work (Braat-Eggen et al. 2021). Moreover, specific attentional capture occurs when the content of the sound distracts individuals from the primary task, such as hearing people's names. One more method of attentional catch is that a particular sound catches consideration, because of the setting wherein it happens.

With lighting ergonomics being a critical design in a workplace, having the proper illumination level, noise level, temperature, and workplace design is crucial to the performance of workers as these have a significant effect on workers' health, mood, comfort, satisfaction, and efficiency. Having poor working conditions can lead to various problems that could potentially decrease efficiency, cause health problems, and cause accidents. Workplaces like laboratories need proper setup as these kinds of workplaces require tasks that need to be seen clearly to avoid errors. Such results of the studies may help raise awareness among institutions to ensure that suitable working conditions are observed in their workplaces to prevent adverse effects on the performance and efficiency of the individual, their well-being, and their satisfaction.

3. Methods

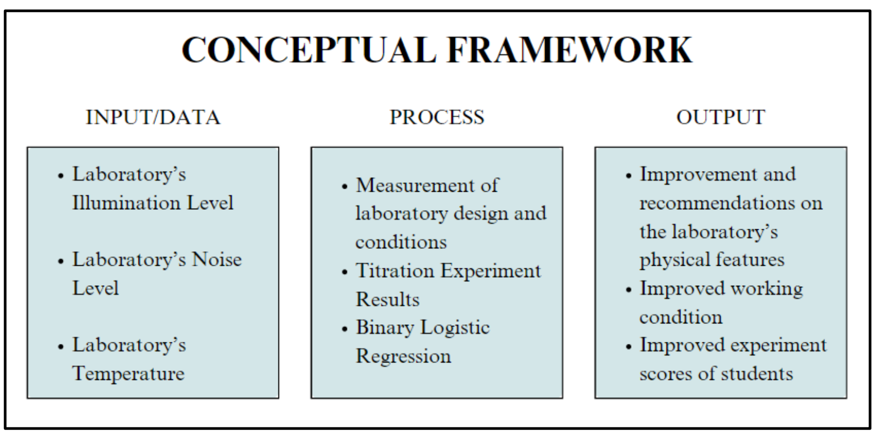

Figure 1. Conceptual Framework of the Study

The research methodology employed in this study is intricately interwoven with the Input-Process-Output (IPO) conceptual framework. Figure 1 shows the guiding framework of the study, emphasizing the various environmental factors in the laboratory: illumination level, noise, and temperature. These independent variables, which are the fundamental inputs in this study, are methodically presented and further incorporate the process phase in the shown framework. This methodology involves the collection and analysis of data to examine relationships between the independent and dependent variables. In pursuit of reviewing and analyzing the relevance and effects of these environmental factors on the laboratory activity performance of Chemical Engineering students, a comprehensive approach to data collection is implemented. The quantifiable measurements of the independent variables are measured using instruments: a Lux meter for the illumination level, a sound-level meter (SLM) for the noise levels, and a temperature humidity gauge for the temperature.

The process phase involves the application of Binary Logistic Regression analysis, which is used to model the relationship between a set of independent variables and a binary dependent variable. This data collection method was used to examine the relationship between illuminance, noise level, temperature, and the student's performance, to understand how independent variables influence the dependent variable of the experiment results individually or as a whole. To achieve this, the SPSS statistical software was used. This approach promotes a comprehensive understanding of the relationship among illuminance, noise level, and temperature. and the results of the students' experiments. The findings from this study can provide valuable insights into the optimal environmental conditions that can affect the students' results in the given experiment.

4. Data Collection

The data-gathering procedure involves several steps. Coming before all others, the researchers will measure the illumination, noise level, and temperature in the Chemical Engineering Laboratory 11 in Fr. Roque Ruano building and gather the rate of satisfaction of the students. This measurement will provide quantitative data on laboratory design and other factors that may influence the student's experiment score.

The Titration experiment to be conducted in this study will be a basic one, simply with the desired goal of turning the solution colorless, indicating the success of the experiment. After the Titration experiment is completed, the researchers will collect the results of each student with their consent. These results represent the dependent variable, reflecting the students' performance during the laboratory activity. The researchers will gather this data to conduct the regression and correlation analysis. By following this data-gathering procedure, the researchers obtained information on the environmental factors. The activity results collected allowed for the study of the relationship and cause and effect between laboratory design and experiment scores while considering the impact of other variables.

5. Results and Discussion

5.1 Numerical Results

As shown in Table 1, among the 162 students who performed the titration experiments, 139 were successful in achieving the desired result of the Titration Experiment, which is 85.8% of the sample size. Meanwhile, 14.2% failed to reach the goal end result of the experiment.

Result	Frequency	Percentage
Success	**139**	**85.8%**
Fail	**23**	**14.2%**

Table 1. Titration Experiment Results

Using specific tools and equipment to measure the environmental conditions in the Chemical Engineering Laboratory 11, the range of the measures of the lighting, temperature, and noise levels inside the laboratory were taken. Table 2 shows the recommended and actual levels of the given factors.

	Recommended Levels	Actual Levels
Lighting Level (in *Lux*)	**500 lux**	**153.8 - 154.9**
Temperature (in *°C*)	**21-25 *°C***	**22.85 - 23.1**

Noise Levels (in *dB)*	**85-90 dB**	**62.5 - 77.9 *dB***

Table 2. Ranges of the Environmental Conditions in ChE Laboratory 11

Through the use of IBM SPSS statistical software, the researchers were able to thoroughly analyze the independent variables and their statistical significance in influencing the results of the dependent variables, which are illumination levels, noise levels, temperature, and the experiment performance. Binary Logistic Regression analysis was performed between the independent variables to the dependent variable.

There should be no multicollinearity or high intercorrelations between the predictors. This is observed by a correlation matrix among the predictors. In an article made by Investopedia (2023), a Variance Inflation Factor or VIF equal to 1 indicates that variables are not correlated, however, variables greater than 5 then state that variables are highly correlated. Hence, figure 2 shows that all of the variables were compliant with the assumption as all of the VIFs are below 5.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-.030	8.304		-.004	.997	-16.442	16.382		
	Lighting	-.058	.036	-.154	-1.634	.105	-.129	.012	.694	1.440
	Temperature	.381	.207	.197	1.841	.068	-.028	.790	.534	1.874
	Noise	.018	.004	.443	4.183	<.001	.010	.027	.547	1.828

a. Dependent Variable: Experiment Result

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	Lighting	Temperature	Noise
1	1	3.995	1.000	.00	.00	.00	.00
	2	.005	27.064	.00	.00	.00	.54
	3	2.082E-5	438.022	.00	.29	.43	.44
	4	3.714E-6	1037.138	1.00	.71	.57	.02

a. Dependent Variable: Experiment Result

Figure 2. Multicollinearity Diagnostics

5.2 Results of Binary Logistic Regression

The classification table, shown in Figure 3, provides the first two percentages which indicate the model's specificity and sensitivity for estimating group membership on the dependent variable. The specificity of this model indicates the percentage of failed experiment results (0=Fail) which is at 0%. The sensitivity of this model indicates the percentage of successful experiment results of the students which is at 100%. The classification table then shows the overall percentage of 85.8% which indicates the rate of correct classification that a student would successfully do the experiment procedure.

Classification Table[a,b]

Observed			Predicted Experiment Result Fail	Predicted Experiment Result Success	Percentage Correct
Step 0	Experiment Result	Fail	0	10	.0
		Success	0	139	100.0
	Overall Percentage				93.3

a. Constant is included in the model.

b. The cut value is .500

Figure 3. Classification Table of Factors

The Omnibus Tests of Model Coefficients were utilized to test the model's parameters' significance. As exhibited in Figure 4, the Hosmer and Lemeshow test is also used to test the Model fit. In the Hosmer and Lemeshow test, if the significance value is less than 0.05, the model indicates a poor fit. In this study, the model fits the data given that the significance value is 0.710 making it greater than 0.05. The model adequately fits the data as the values between observed and predicted models are approximately equal.

Contingency Table for Hosmer and Lemeshow Test

		Experiment Result = Fail		Experiment Result = Success		
		Observed	Expected	Observed	Expected	Total
Step 1	1	4	4.444	8	7.556	12
	2	4	2.667	20	21.333	24
	3	2	1.302	13	13.698	15
	4	0	.572	13	12.428	13
	5	0	.337	16	15.663	16
	6	0	.064	4	3.936	4
	7	0	.515	37	36.485	37
	8	0	.059	9	8.941	9
	9	0	.040	19	18.960	19

Figure 4. Contingency Table for Homes and Lemeshow Test

Analysis of Variance was used by the researcher to assess whether letting the Industrial Engineering student to take the experiment, due to the lack of a Chemical Engineering student to attend due to the conflict of schedule, have affected the result of the experiment. In addition, factors are also considered to see whether environmental factors such as lighting, noise, and temperature might affect Industrial Engineering's performance as well.

ANOVA - Result

Cases	Sum of Squares	df	Mean Square	F	p
Program	0.816	1	0.816	6.897	0.009
Residuals	18.919	160	0.118		

Note. Type III Sum of Squares

Descriptives

Descriptives - Result

Program	N	Mean	SD	SE	Coefficient of variation
1	120	0.900	0.301	0.028	0.335
2	42	0.738	0.445	0.069	0.603

Figure 5. ANOVA Result

As shown in figure 5, it shows that there is a significant difference among the groups or factors in the study, as supported by the low p-value, which is less than 0.05, in the between-groups comparison. These data suggest that at least one group in this data set is significantly different from the others. However, the variance within the groups is relatively low, which supports that there really is a difference that is not due to random chance but rather attributed to the disparities between the groups, which directly affects the success rate of doing the experiment.

5.3 Proposed Improvements

This study provided several suggestions to enhance the learning setting in the laboratory:

1. Improve Lighting: Upgrading lighting solutions to reach the recommended brightness level of 500 lux could boost comfort and potentially enhance student performance.
2. Precise Temperature Management: Introducing HVAC systems for tailored temperature regulation to maintain conditions for focus and stability during experiments.
3. Integrated Environment Controls: Using noise-canceling devices and absorbent materials to reduce distractions and enhance concentration levels during work.

4. Sustainability Initiatives: Encouraging students and technicians to be involved in selecting materials for experiments promoting eco practices and hands-on learning experiences.
5. Technology Integration: Incorporating energy lighting and temperature control systems to save energy and create a learning environment.

5.4 Validation

For the study, researchers carefully examined whether the environmental conditions in Chemical Engineering Laboratory 11 at the University of Santo Tomas have an impact on the results of student's titration experiments. Through the use of Binary Logistic Regression analysis, it was discovered that a relationship between the conditions in the controlled laboratory—such as lighting, temperature, and noise levels—and the student's achievements. This connection resulted in an 85.8% success rate during titration experiments. These findings indicate that optimized laboratory settings ultimately play a role in enhancing educational results within experimental setups for students.

6. Conclusion

The study gave insights into how the design of laboratories including factors like lighting, noise levels, and temperature conditions affects the performance of Chemical Engineering students at the University of Santo Tomas during titration experiments. By using a quantitative approach and Binary Logistic Regression analysis a positive connection between ideal lab conditions and student success rate has been identified. These results emphasize the role that the learning environment plays in shaping educational outcomes emphasizing the importance for schools to prioritize creating optimal laboratory settings.

One notable aspect of the study is its statistical analysis that quantifies how each environmental factor impacts experiment results. This data-driven method provides suggestions for improving lab designs allowing educational institutions to go beyond basic functionality and actively contribute to student welfare and academic achievements. In general, this study marks a step in grasping the complex relationship between the physical environment and academic achievements. It opens up possibilities for creating effective learning environments customized to meet the unique requirements of fields such as Chemical Engineering.

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Biography

Renzo Miguel M. Lanip is a 4th year Industrial Engineering student at the University of Santo Tomas. He has exhibited a strong commitment to strive in terms of excellence and growth both in personal and in academics. He has gained experience and has developed in his role as an Executive Associate at the Cisco Networking Academy Gateway's Creatives Department, in which he has shown proficiency in networking technologies and their creative talents in the field. He had his internship at the Office of the QS/THE Rankings at the University of Santo Tomas, where he has acquired significant knowledge and skills that have contributed to his personal and professional development. Throughout his experiences, he has shown the spirit and ability to grasp various skills, and adapt in diverse environments.

Therese Adrianne M. Macawile is a 4th Year Industrial Engineering student at the University of Santo Tomas. She has developed her academic excellence and gained expertise in school administration by being an executive associate for the school organization Cisco Networking Academy Gateway (CNAG). She took her internship in the Industry, Government, Alumni and Academe Relations Program (IGAARP), a relations arm of the UST Faculty of Engineering. During her time working, she gained invaluable experience and knowledge that aided in the advancement of multiple firm projects on a professional level as she formed profound relationships with the academic, governmental, and business communities as well as with the Thomasian engineers she met as they deliver academic programs that help the organization achieve its goal in making more employable future graduates.

Czarina Danielle B. Mendoza is a 4th Year Industrial Engineering student at the University of Santo Tomas. She decided to continue her studies at the University because of the school culture and academic competitiveness she witnessed during her stay at UST SHS. She has honed her skills in different areas while studying in the University and joining different organizations like ORSP-UST and CNAG. During her time studying at the University of Santo Tomas, she has learned the importance of handling various responsibilities with poise and professionalism.

Damirson A. Co, PIE is an adjunct professor in the Department of Industrial Engineering at the University of Santo Tomas. He earned his Bachelor of Science degree in Industrial Engineering from the University of Santo Tomas and a Master of Science degree in Industrial Engineering Major in Production Systems from the University of the Philippines – Diliman.