Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator

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ABSTRACT-The main purpose of this study was to design, assemble, and assess the efficiency, degree of effectiveness as a tool for instruction and acceptability of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator. This study was conducted at Bohol Island State University (BISU) Main Campus, Tagbilaran City in the second semester of the academic year 2020-2021. This study was conducted mainly to bridge the gap between the industry and the university as the latter embraces Industry 4.0 characterized by rapid technological advancements which employs automation and artificial intelligence incorporated in HVAC systems. The study employed the experimental research design in developing the device in the assessment of its efficiency. The descriptive design was used to determine the acceptability of the simulator. The observation revealed that the simulator was efficient in terms of cooling and dehumidification. In the ventilation function, all the devices were functional and the simulator was able to ventilate the system except for its outside humidity sensing feature. This was because this feature is not really applicable in tropical countries like the Philippines. However, it was included for presentation purposes only since the device was designed for instruction. As to the degree of effectiveness, it was found out that there was a significant increase in the performance of students after they were virtually exposed to the simulator. This was observed in the results of the post-test which they obtained greater average rating of 1.5 described as "Very Good" while the pre-test average rating was 4.0 described as "Poor". The acceptability of the device had an average weighted mean of 3.77 and was described as "very high". The results proved that the device is suitable to be used as a tool for instruction.
Keywords: *Demand-Controlled, Ventilation, Commercial Air-Conditioning, HVAC*

INTRODUCTION

Educational institutions play a great role in molding a country's economy by preparing its citizens to become the human resources capable of bringing development and progress to the welfare of the whole nation. Schools are considered as the training ground for students to acquire necessary knowledge and skills prior to nation building. The ultimate task for schools is to make sure that students become the persons with the qualities that the industry demands. Thus, schools should design its facilities with similarities with that of the industry.

In the Philippines, a statement on April 27, 2021 by the president of the Philippine Chamber of Commerce and Industry (PCCI) said that with the new competencies emerging in the workplace under Industry 4.0, there is a need to equip learners with skills and tools to navigate the changing environment. He uttered this statement after the Institute for Management Development's World Talent Ranking report released last year found out that Filipino workforce ranked 48th out of 63 economies evaluated.

With the advancement of technology and its shift to Industry 4.0, the institution has to upgrade its facilities to meet the industry demands on manpower. Educational institutions are geared towards equipping the people with pertinent knowledge and skills which are needed in the industry. The challenge on these educational institutions becomes greater since the introduction of the Industry 4.0. They have to be updated with the latest trends of technology in order to supplement the demands of the industry of a highly-competent workforce. The fourth principle of Competency-Based Training states that training is based on work that must be performed and that learning is based on the actual industry practice (National TVET Trainers Academy, 2012). It implies that to be able to prepare the person in the industrial realms, training institutions must replicate the environment present in the industry.

John Dewey's Experiential Learning Theory asserts that an actual and practical approach contributes a lot to the development of a student's skills and ideas. Learning and memory retention is enhanced and enriched when both physical and mental capacities are used (Thompson, 2010). This has been adapted by educational institutions in their curricular offerings to include hands-on activities to ensure learning of students.

Bohol Island State University (BISU), a premier science and technology university, is committed to provide quality higher education in the arts and sciences. As a response to the challenges of Industry 4.0 on the education sector, the institution is doing its best to be up-to-date by encouraging its faculty members to involve in research and development activities. Moreover, research projects of undergraduate, graduate and post-graduate students and even that of the faculty are encouraged, if not required, to anchor on Industry 4.0.

A study in Indonesia in 2018 revealed that training laboratories found the fact that students can remember 5% to 10% of what they have read in textbooks, but they can remember up to 80% of what they have experienced. Practical activities are suitable activities to support students in remembering and understanding more subjects through direct experience (Lizelwati & Chandra, 2018. With many benefits that can be taken from practicum activities, lecturers need to be able to design and prepare practicum activities (Trianto, 2010).

In connection to this, the researcher designed and developed the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator. It is an instructional device inspired by the trends in HVACR brought by Industry 4.0. It provides a smart HVACR system using modern equipment to cater the needs of students to learn installation and troubleshooting of air-conditioning and ventilation system. Artificial Intelligence (AI), as one of the highlights of Industry 4.0, has promising applications to HVACR Technology, since it can improve both energy efficiency and indoor environmental quality. AI can optimize variables like airflow, temperature, and humidity. It simply means conserving air quality with the lowest possible energy consumption (Bipat, 2020).

It is a simulator that replicates one of the latest developments in HVACR technology which is the Demand-Controlled Ventilation. This system refers to any means by which the breathing zone outdoor airflow can be varied to the occupied space and ventilation requirements of the occupied zone (American Society of Heating, Refrigerating and Air-conditioning Engineers, 2017). This becomes possible with the use of sensors like CO_2 and a ventilation system that continuously reads the sensor data and, based on CO_2 levels, automatically directs the air handling units to adjust the outside air intake. This system reduces the work for the heating and cooling units and maintains consistent, healthy, air quality at the same time (Davies, 2019).

The simulator has a very specific purpose of providing room occupants of a thermal comfort and good air exchange, respectively. The temperature ranging between 22^0C-27^0C and relative humidity ranging between 30-60% is described by ASHRAE as the thermal comfort requirements. To achieve this, programmable thermostat is installed to operate based on temperature and relative humidity inside the room. It controls the air-conditioner on when and how long to operate. Thus, the simulator has to achieve these given values to provide the occupants the comfort they need. HVACR systems are designed to achieve the environmental requirements of the comfort of occupants. These systems are more used in different types of buildings such as industrial, commercial and institutional buildings. Its main goal is to satisfy the thermal comfort of occupants by adjusting and changing the ambient air conditions to the desired conditions of occupied buildings (Seyam, 2018).

In terms of good air exchange, ASHRAE Standard 62 typically states that CO_2

measurements found in buildings should be at a maximum of 1000 parts per million (ppm). This is considered to be compliant to the good air exchange requirement. To achieve this, a Non-Dispersive Infrared Radiation sensor is used to measure the level of CO_2 in the room. It triggers the operation of the exhaust fan which is to draw CO_2-laden inside air and introduce fresh air through an air vent. This process is called ventilation but specifically, CO_2-based ventilation is known as demand-controlled ventilation. The desired result of an air distribution system in an industrial building room is to bring fresh air, to compensate the need for heat or cold to create a pleasant ambiance in the area of occupation (Popa & Popa, 2018). There is also a need to monitor CO_2 concentration in public indoor places in real-time. A higher level of CO_2 concentration could harm the occupants' health (Zhang, et. al, 2017). To measure the amount of CO_2 concentration in air, the principle of Non-Dispersive Infrared Radiation is applied. An infrared (IR) lamp directs waves of light through a tube filled with sample of air toward an optical filter in front of an IR light detector. It measures the amount of IR light that passes through the optical filter.

In a survey on Norweigian schools, using CO_2 sensors for DCV was found to reduce energy consumption by 62% when compared with a constant air volume (CAV) ventilation system (Mysen, et.al, 2017). The efficiency of CO_2 sensors gave the researcher the idea of incorporating it in crafting the instructional device.

For the automation of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator, a Programmable Logic Controller (PLC) is utilized. PLCs are computer-based, solid-state, single processor devices that emulate the behavior of an electric ladder diagram capable of controlling many types of industrial equipment and entire automated systems. They are usually the main part of the automatic systems in the industry (Bayindir, 2011). PLC control systems have been designed to be easily installed and maintained. With the use of the Happy Haiwell Programming Software, troubleshooting is simplified by the use of fault indicators and messaging displayed on the programmer screen. Input/output modules for connecting the field devices are easily connected and replaced (Petruzella, 2011).

To come up with the latest trends in automation of HVAC equipment, the use of Human Machine Interface (HMI), for instance, will allow greater product customization (Strange & Zuchella, 2017). In the study of Popa and Popa (2018), they used a Simatic HMI 377MP type. It is extremely reliable with the main purpose of providing a means of monitoring and control easy to use by maintenance personnel. On the screen, the user can view the operation of the monitored systems as well as the buttons for controlling them. The control is accomplished by accessing 8 screens for each process. Supervisory Control and Data Acquisition (SCADA) is mainly used for transmission and distribution networks in industrial buildings. The HMI used in the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator is Haiwell 4x7” HMI compatible with the Haiwell AT12MOR PLC and connected via Ethernet cable. The HMI serves as the monitoring and controlling device for the operation of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator. Humidity, temperature, and CO_2 concentration level are displayed on the HMI. Moreover, adjustments of these parameters on the user's preference can also be done in the HMI.

The Demand Control Ventilation for Commercial Air-Conditioning System Simulator is an instructional device that would help improve the teaching techniques of instructors. This device can be used to deliver quality education to students of HVACR Technology. This device is designed under the motivation to address the inadequacy of learning tools that students use in learning the commercial applications of air-conditioning. This can be used to assist the teachers in imparting lessons. This may be an effective tool to transmit information and ideas to the learners. This lies in the conjunction with the Stimulus Condition which stressed, that in learning the more frequently a stimulus and a response are associated with each other, the more likely the particular response will follow the stimulus (Domjan, 2014).

However, due to the present global COVID-19 pandemic, schools are not allowed to conduct face to face classes. This led to a shift from the aforementioned mode of holding classes into conducting classes in a virtual setting through online platforms such as Google Meet, MS Teams, Zoom, FB Messenger, among others. Theory of Online Learning can be seen in the concept that the computer and internet are used to deliver course content in technology enhanced learning environment. It covers the learning-teaching activities in the cognitive and/or psycho-motor and affective domains of an individual learner. In connection to this, the simulator was shown to the students in a virtual set-up, having discussion and demonstration through Google Meet.

With the creation of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator, the researcher adheres to the university's goals and objectives to enhance, develop and mold the knowledge and skills of students for the formation of a world-class and virtuous human resource for the development of Bohol and the country. The researcher believes that this development starts when students are exposed to an environment and facilities in school which replicates the actual work in the industry.

METHOD/S

The study employed the experimental research design in the development of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator. The device was carefully designed, assembled and tested for its efficiency to ensure that it was working according to the desired operation. Experimentation was conducted upon assembly to meet the most desired outcome in cooling and dehumidifying the inside air, and in ventilation function. Meanwhile, its effectiveness as a tool for instruction to impart knowledge to students was evaluated using one-group pre-test and post-test design.

Afterwards, descriptive survey method was employed with the use of a questionnaire to assess the acceptability level of the simulator in terms of efficiency, as a tool for instruction, convenience, safety and cost.

The study was conducted at Bohol Island State University Main Campus, Tagbilaran City in the second semester of the Academic Year 2020-2021. This institution was chosen by the researcher since it is equipped with the facilities needed for designing and assembling the simulator.

Moreover, it is the institution where the researcher practices his career in teaching HVACR Technology. He intended to use this simulator in his delivery of lessons about the operation of the commercial HVACR system.

This study employed thirty-eight (38) respondents. Purposive sampling method was utilized in choosing fifteen (15) experts who assessed the efficiency and acceptability level of the simulator. They were composed of five (5) experts in Refrigeration and Air-Conditioning (RAC) Technology and five (5) experts in Electrical Technology employed in private commercial establishments within Tagbilaran City specifically the Bohol Quality Mall, AH Shoppers' Mart and Alturas group of companies, three (3) Electrical Technology instructors and two (2) mechanical engineers employed in BISU. They were chosen as respondents since they have the technical knowledge of the actual operation of commercial ventilation systems. They answered the questionnaire to assess the acceptability level of the simulator.

Moreover, twenty-three (23) students of BISU Main Campus were selected as respondents to determine the effectiveness of the simulator. They were the whole population of the 3rd year BS in Industrial Technology major in HVACR Technology students. They were chosen since these students have prior knowledge in commercial ventilation systems in the previous year level.

RESULTS AND DISCUSSION

This chapter presents the findings, analysis and interpretation of the study. Data were gathered, collated and tabulated in accordance with the specified questions. The data were supported with tables which illustrate the responses of the study in terms of efficiency, degree of effectiveness as a tool for instruction and acceptability level of the Demand-Controlled

Ventilation for Commercial Air-Conditioning Simulator.

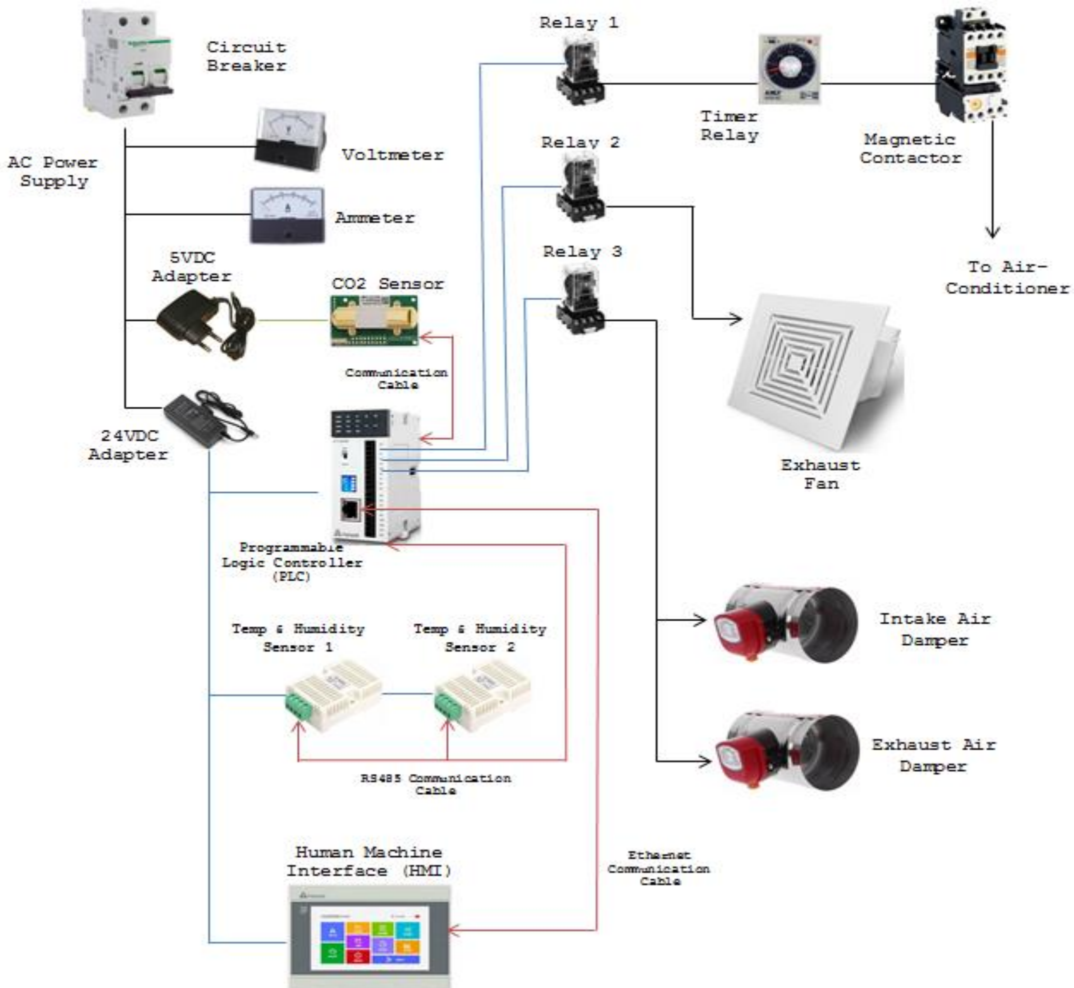

Figure 1. Pictorial Diagram of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator

Efficiency of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator Cooling and Dehumidification

Table 1

Function	Thermal Comfort Requirements	Operation	Actual Reading	Result	Interpretation
Cooling And	Temperature 22-27^{0}C	Air-conditioner operates to	22.0^{0}C	The prescribed temperature was achieved	Functional

Dehumidification		achieve the prescribed temperature	$22.0^{0}C$	The prescribed temperature was achieved	Functional
			$22.0^{0}C$	The prescribed temperature was achieved	Functional
	Humidity 30-60%	Air-conditioner operates to achieve the prescribed humidity	44.4%	The prescribed humidity was achieved	Functional
			44.6%	The prescribed humidity was achieved	Functional
			44.3%	The prescribed humidity was achieved	Functional

Table 1 shows the efficiency of the Demand-Controlled Ventilation for Commercial Air-Conditioning System in terms of cooling and dehumidification. With this efficiency, the simulator was able to achieve the thermal comfort requirements in terms of temperature and humidity.

One of the main functions of air-conditioning is to cool and dehumidify the air in an enclosed space. It works based on the Second Law of Thermodynamics which states that heat always transfers from hot to cold. Heat within the room transfers to the cold air coming out from the evaporator of the air-conditioner. This process repeats until the desired temperature inside the room is achieved.

The temperature and humidity sensor is responsible for controlling the cooling and dehumidification function of the simulator. Once the actual air temperature and humidity inside the room goes beyond the prescribed range stated above, the sensor sends signal to the PLC to close its internal relay contacts. This resulted to triggering the magnetic relay to close its contact to allow 220 VAC to flow into the timer relay coil. The timer relay delays the turning on of the magnetic contactor for 3 minutes. After the given time, it closes its contacts allowing 220 VAC to flow into the magnetic contactor coil. The normally open contacts of the magnetic contactor closed immediately to let 220 VAC power the window-type air-conditioner. The air-conditioner is the output device which is responsible for cooling and dehumidifying the inside air.

Efficiency of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in terms of Ventilation

Table 2

Function	Air quality parameters	Operation	Actual Reading	Result	Interpretation
Ventilation	CO_2 Level 1000 ppm	Exhaust fan operates when	1080 ppm	Brought down the CO_2	Functional

		CO_2 level goes beyond 1000 ppm		level to normal	
			1060 ppm	Brought down the CO_2 level to normal	Functional
			1080 ppm	Brought down the CO_2 level to normal	Functional
	Outside air Temperature 22-27^{0}C	Exhaust fan operates when outside air temperature is between 22-27^{0}C	26.8	Outside air introduced to the simulator	Functional
			27.0	Outside air introduced to the simulator	Functional
			26.9	Outside air introduced to the simulator	Functional
	Outside Humidity 30-60%	Exhaust fan operates when outside humidity is between 30-60%	70.3%	Exhaust fan did not operate	Not functional
			67.8%	Exhaust fan did not operate	Not functional
			72.6%	Exhaust fan did not operate	Not functional

Ventilation refers to the introduction of fresh air into an enclosed space. It is very important not only to circulate the air inside a room but also to ensure that adequate amount of fresh air enters the system. With this, the room occupants are able to avoid problems such as sleepiness, headaches, dizziness, poor concentration, loss of attention, increased heart rate or even nausea due to a high concentration of carbon dioxide in the inside air. ASHRAE Standard 62 typically states that CO_2 measurements found in buildings should be at a maximum of 1000 ppm. This is considered to be compliant of the good air exchange requirement.

To measure the amount of CO_2 concentration in air, the principle of Non-Dispersive Infrared Radiation is applied. An infrared (IR) lamp directs waves of light through a tube filled with sample of air toward an optical filter in front of an IR light detector. It measures the amount of IR light that passes through the optical filter. In the table above, it was shown that the CO_2 sensor successfully sent signal to the PLC to close its internal relay contacts, which triggered the magnetic relay to close it normally open contacts. This provided the output devices, exhaust fan and air dampers to run and carry out its function to extract inside air and introduce fresh air into the simulator. This way, CO_2 concentration broke down and went back below 1000 ppm.

Another means of ventilation was through the use of outside air temperature and humidity sensor. When either or both outside air temperature and humidity reached the thermal comfort requirements of 22^{0}C-27^{0}C and relative humidity ranging between 30-60% is described by ASHRAE, this sensor sends signal to the PLC to close its internal relay contacts, which triggered the magnetic relay to close it normally open contacts. This way, exhaust fan and air dampers ran and introduced fresh air into the system. With regards to the CO_2 level outside, this do not have a problem since global average atmospheric CO_2 in 2021 was only 417.8 ppm, a value which is within the range of 1000 ppm.

Since the setting is in the Philippines, outside air temperature and humidity the thermal comfort requirements of 22^0C-27^0C and relative humidity ranging between 30-60% was very difficult to achieve. In terms of outside temperature, the lowest temperature recorded was 26.8^0C. This value was still within the temperature range which allowed ventilation to take place. However, in terms of humidity, according to PAG-ASA the average humidity in the country is 81.0%. It is not within the range to meet thermal comfort requirements, resulting to non-functionality of this feature. This is not applicable to a tropical environment, yet this simulator is intended to be used as an instructional device so it justifies the inclusion of this feature since this is really present in actual commercial HVAC systems abroad.

Table 2 shows the efficiency of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in terms of ventilation. The simulator was able to neutralize CO_2 level above 1000 ppm back to normal. The CO_2 sensor sent signal to turn on the exhaust fan and introducing fresh air to the simulator. With this efficiency, the simulator was able to achieve the typical level of good air exchange requirements in terms of CO_2 concentration.

Pre-test and Post-test Results of Students using the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator
n = 23

Table 3

Range Rating	Description	Pre-test			Post-test		
		Freq.	%	Rank	Freq.	%	Rank
1.0-1.2	Excellent	0	0		0	0	
1.3-1.5	Very Good	0	0		12	52.17	1
1.6-2.5	Good	0	0		11	47.83	2
2.6-3.0	Fair	1	4.35	2	0	0	
3.1-5.0	Poor	22	95.65	1	0	0	
Average Rating		**4.0**			**1.5**		
Description		**Poor**			**Very Good**		

Table 3 shows the frequency and percentage of students' performance in both pre-test and post-test.

It reveals that the average pre-test rating of students was 4.0, described as "Poor". It was expected since they have not encountered the demand-controlled ventilation system in their lower years, though there were topics related to commercial ventilation systems. This result implied that these students have very little knowledge in this type of ventilation system. This signifies the need for them to get educated on this matter.

Meanwhile, the post-test shows higher results in comparison to the pre-test. The average rating was 1.5, described as "Very Good". However, it was observed that almost half of them only got "Very Good" rating while the other half only got "Good". It only implied that the virtual discussion and demonstration, though helpful as a means to deliver classes in technical subjects, has also some weak points due to other factors such as poor internet connection, problematic gadgets, noisy environment, among others according to students based on their experiences while conducting the virtual meeting.

The results of the post-test showed that there was a noticeable change in the knowledge gained by the students. This is supported by the Theory of Online Learning which can be seen in the concept that the computer and internet are used to deliver course content in technology enhanced learning environment. It covers the learning-teaching activities in the cognitive and/or psycho-motor and affective domains of an individual learner. Their learning increased when they were virtually exposed to the simulator and they were shown of the operation of the simulator even in a virtual setting.

Difference between the Pre-test and Post-test of the Students
n = 23

Table 4

Difference	Computed t-Value	Tabular t-Value	Interpretation	Decision
	at 0.05 level of significance, df=22			
Pre-test and Post-test	±24.35	±2.07	Significant	Reject the Null Hypothesis

Table 4 shows the difference between the pre-test and post-test performance of students. It shows that the computed t-value of ±24.35 is greater than the tabular t-value of ±2.07 at 0.05 level of significance with 22 degrees of freedom. Therefore, there was a significant difference in the performance of students before and after they were virtually exposed to the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator. This also made the null hypothesis to be rejected.

Acceptability Level of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator
n = 15

Table 5

Acceptability Level	WM	Desc	Rank
5.1 Efficiency			
1. Achieves thermal comfort requirements for occupants.	3.80	VH	1.5
2. Achieves good air exchange requirements for occupants.	3.73	VH	
3. Provides identical operation with regards to commercial HVAC systems.	3.87	VH	
4. Provides technical training system that could provide the same knowledge and skill outcomes as the larger systems.	3.73	VH	
5. Features modern and industry-standard sensors, switches and automation devices present in commercial establishments.	3.93	VH	
Average	**3.81**	**VH**	
5.2 As a tool for instruction			1.5
1. Students were able to increase the efficiency from pre-test to post-test.	4.00	VH	

2. Students can practice in commercial HVAC and expand their skill-set to advanced Industry 4.0 operations.	3.67	VH	
3. Provide different perspectives to the instructor's knowledge in the field of commercial HVAC.	3.80	VH	
4. Enables educators to deliver instruction much easier to its learners in the field of commercial HVAC.	3.73	VH	
5. Provides vital training experience for learners and professionals that will perform installation, maintenance, servicing and troubleshooting of commercial HVAC system.	3.87	VH	
Average	**3.81**	**VH**	
5.3 Convenience			4
1. Ports and terminals for input and output module are readily accessible.	3.73	VH	
2. Device is movable from one place to another.	3.73	VH	
3. Less hard wiring is used.	3.73	VH	
4. Monitoring and control of air quality parameters are in one monitor only.	3.67	VH	
5. Requires very little effort to set air quality parameters due to the touchscreen feature.	4.00	VH	
Average	**3.77**	**VH**	
5.4 Safety			3
1. Equipped with over-current and short circuit protection for the simulator.	3.80	VH	
2. Electrical components are all properly grounded.	3.87	VH	
3. Electrical components are properly rated according to specified voltage and current.	3.73	VH	
4. Composes a frame made of non-conductive material.	3.93	VH	
5. Conductors are all properly insulated.	3.67	VH	
Average	3.80	**VH**	
5.5 Cost			5
1. The Demand-Control Ventilation for Commercial Air-Conditioning Simulator has a total cost of **P76,477.00**	3.67	VH	
Average	**3.67**	**VH**	
Average WM	**3.77**	**VH**	

Table 5 shows the summary of acceptability level of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in terms of efficiency, as a tool for instruction, convenience, safety and cost.

The results showed that the acceptability level of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator achieved the highest rank both in terms of efficiency and as a tool for instruction with a rating of 3.81 and were interpreted as "very high". It implied that the simulator did functioned according to its desired operation in terms of bringing the temperature and humidity of the inside air to meet the thermal comfort requirements, and also in terms of neutralizing the amount of CO_2 concentration through allowing fresh air to be introduced within the air-conditioned space. Also, the components involved in carrying out cooling and dehumidification of air, and ventilation function according to its specified functions. Moreover, the simulator was observed to be very effective in providing students with the necessary knowledge through virtual demonstration of the parts, functions and actual operations of the demand-controlled ventilation system.

Cost was described as "very high" but was ranked the lowest with a rating of 3.67. The assembly of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator reached the amount of 76,477.80 because the materials used were guaranteed to have quality to provide better performance during operation. Selecting the suitable material for a specific application is always considered in constructing instructional tools for imparting knowledge to students (Dym, et. al., 2004). Despite of this, the cost of assembling the device is much lesser compared to very huge equipment present in the industry which costs hundreds of thousands or even millions.

The overall weighted mean of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator was 3.77, described as "very high". The respondents assessed the device to be very highly acceptable to be used for instruction as a simulator emulates the industry processes and standards. Moreover, it gives convenience to the user due to the presence of an automated control system, guaranteed to provide safety to its user and comes at a very acceptable cost.

Findings

The following are the findings based on the result of the data obtained:

1. On the description of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in terms of its preparation, design, procedure, tools, equipment, materials and cost, and parts and functions.

The Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator is designed to be an instructional device used to simulate a smart ventilation system employed in commercial establishments in complement to the air-conditioning system where it operates under the demand of factors such as temperature, humidity and CO_2 concentration as determinants of good air quality. It is composed of a simulation room with an air-conditioning system, a CO_2-based ventilation system and a smart electrical control and monitoring system. Materials used for the device were carefully selected with guaranteed high quality. The total cost of assembling the simulator was seventy-six thousand four hundred and seventy-seven peso and eighty centavos (Php76,477.80). The prescribed procedure was followed on how to run the device according to the desired operation.

However, the design of the device made it difficult to transport due to its bulky weight. It is also hard for the device for access on small room openings for the same reason.

2. On the Efficiency of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in terms of cooling, dehumidification and ventilation.

The Demand-Controlled Ventilation for Commercial Air-Conditioning System was able to achieve the thermal comfort requirements in terms of its cooling and dehumidification functions and good air exchange requirements in terms of ventilation. All its parts and components were listed as functional.

However, in the ventilation function, the outside temperature and humidity sensor was not able to function due to the Philippine climate which made the feature not applicable. However, for presentation purposes as an instructional device, this feature is still helpful.

3. Degree of Effectiveness of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator

The results of students' performance were computed with the aid of the prescribed statistical treatment. It was found out that an increase of learning took place after students were virtually exposed to the simulator where they were demonstrated with its functions and operation. This was noticed in the post-test results of the students by which they obtained higher ratings in comparison to their pre-test results. The post-test average rating was 1.5 interpreted as "Very Good". Meanwhile, the average rating of their pre-test was 4.0 interpreted as "Poor"

4. Difference between the pre-test and post-test rating of students upon using the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator.

The pre-test and post-test ratings revealed that the computed t-value of 24.35 was greater than the tabular t-value of 2.07 at 0.05 level of significance with 22 degrees of freedom. This was interpreted as significant and made the null hypothesis rejected. Even with the virtual exposure of the students to the simulator, they obtained better understanding about the subject matter.

5. The Acceptability Level of the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator

The Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator was found to be highly acceptable in the aspects of efficiency, as a tool for instruction, convenience, safety and cost with a total average weighted mean of 3.77 and described as "Very High". Both efficiency and effectiveness as a tool for instruction were ranked the highest with an average weighted mean of 3.81. On the other hand, cost was ranked lowest with an average weighted mean of 3.67. Although it was ranked as the lowest, it was still described as "Very High" by respondents.

Conclusions

Based on the study's findings, the following conclusions were drawn:

The Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator was efficient in terms of cooling and dehumidification and ventilation. It was able to achieve the thermal comfort requirements, good air exchange requirements and its components functioned according to specified operation. Moreover, the simulator was able to increase students' learning after being virtually exposed to it. This increase in learning can be seen in the difference of students' rating in their post-test compared to that of their pre-test rating. Lastly, the device was rated "Very High" in all the criteria of assessing its acceptability level. This means that the experts very highly appreciated the efficiency, effectiveness, convenience and safety of the device to be used for instruction, and this also comes with a very highly acceptable cost.

Recommendations

Based on the data and findings, the researcher offers the following recommendations:

1. The researcher recommends that the design for the simulation room to be changed into a modular design. Instead of fixing the whole simulation room, it will be using special hinges and connectors to make it a folding mini house for better transportation and easier access to small and narrow way.
2. The researcher recommends that the administration will support for the simulator to be patented for its protection through the Innovation and Technology Support Office (ITSO) of the university.
3. It is recommended for the shop instructor to introduce the Demand-Controlled Ventilation for Commercial Air-Conditioning Simulator in the curriculum of the BS and Diploma in Industrial Technology major in HVACR Technology program by incorporating the subject matter in the course syllabus of the HVACR Technology 4 with the course description, "Commercial HVAC Units Servicing".
4. School administrators are encouraged to have their instructors construct instructional devices that replicate the actual functions of machines and equipment present in the industry.
5. A follow up study on the degree of effectiveness of the simulator as a tool for instruction to impart skills on actual installation and troubleshooting of a demand-controlled ventilation system through the administration of

skills test shall be conducted upon the resumption of face to face classes.

References:

[1] American Society of Heating and Refrigerating and Air-Conditioning Engineers. 2013. ANSI/ASHRAE Standard 62.1-2013-Ventilation for Acceptable Indoor Air Quality.

[2] Bayindir, R., Cetinceviz, Y., (2011). A water pumping control system with a programmable logic controller (PLC) and industrial wireless modules for industrial plants-An experimental set-up. ISA Trans 2011; 50: 321-8.

[3] Bipat, C., How Artificial Intelligence Improves HVAC Performance, Nearby Engineers, viewed 24 July 2020, <https://www.ny-engineers.com/blog/how-artificial-intelligence-improves-hvac-performance?hs_amp=true

[4] Davies, M., Save Big On Energy With Demand Control Ventilation, Iota Communications, Inc., viewed 24 July 2020, <https://www.iotacommunications.com/blog/save-big-on-energy-with-demand-control-ventilation/

[5] Domjan, M., 2014. ***The principles of learning and behavior.*** Cengage Learning Philippine

[6] Lizelwati, N. , Chandra, A.N. (2018). Developing instructional devices of generic physics practicum integrated with Al-Quran for department of physics educatin IAIN Batusangkar. IOP Conf. Series: Journal of Physics: Conf. Series 1185 (2019) 012039. DOI: 10.1088/1742-6596/1185/1/012039

[7] Mysen, Mads; Berntsen, Sveinung; Nafstad, Per; Schild, Peter G. (December 2005). "Occupancy density and benefits of demand-controlled ventilation in Norwegian primary schools". *Energy and Buildings*. **37** (12): 1234–1240. doi:10.1016/j.enbuild.2005.01.003

[8] NTTA (2012). Competency – based learning materials; planning training sessions. National TVET Trainers Academy; Technical Education and Skills Development Authority

[9] Petruzella, F.D., 2011. Programmable Logic Controller. 4th ed. McGraw-Hill; 2011. pp.1-396.

[10] Popa, V. & Popa, L., Study on designing an automated system of efficient HVAC control for energy saving in industrial buildings. IOP Conference Series: Materials Science and Engineering, Volume 400, Issue 2.

[11] Seyam, S., (2018). Types of HVAC Systems. DOI:10.5772/intechopen.7892

[12] Strange, R. and Zuchella, A., 2017. Industry 4.0, global value chains and international business. Multinational Business Review, 25(3), pp.174-184. DOI: https://doi.org/10.1108/mbr-05-2017-0028

[13] Thompson,P.(2010).**Learning by doing. Handbook of the economics of innovation,** 1, 429-476

[14] Trianto, Mendesain Modi Pembelajaran Inovatif-Progresif, Jakarta: Kencana Prenada Media Group, 2010.

[15] Zhang, X., Wargocki, P., Lian, Z., Thyregod, C. Effects of exposure to carbon dioxide and bioeffluents on perceived air quality, self-assessed acute health symptoms, and cognitive performance, Indoor Air(1) (2017) pp. 47-64.