RESEARCH AND INNOVATION IN TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING
e-ISSN: 2785-8138

RITVET

Vol. 1 No. 4 (2024) 25-42
https://publisher.uthm.edu.my/periodicals/index.php/ritvet

ABBM Development of Air Duct System with Damper Control

Muhammad Hazim Ahmad Yusri[1], Mohd Hairwan Md Nor[1]*, Khairul Anuar Abdul Rahman[1]

[1] *Faculty of Technical and Vocational Education, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia*

*Corresponding Author: hairwan@uthm.edu.my
DOI: https://doi.org/10.30880/ritvet.2024.04.01.004

Article Info

Received: 3rd March 2024
Accepted: 29th May 2024
Available online: Day Month Year

Keywords

Automatic damper, manual control, HVAC, ABBM, ADDIE

Abstract

The development of teaching aids (ABBM) for the air duct system with damper control is a product produced to facilitate the tasks of teachers and students during teaching and learning (PdP) sessions. sessions conducted in the classroom, especially for air conditioning and refrigeration. This product is produced based on the actual product on the market. However, existing products in the market have a very high cost to obtain to make them as ABBM. Therefore, this product is produced to ensure that students can learn easily by gaining hands-on experience in operating an air duct automatically. The objective of the study is to design, develop and test the functionality of air duct system products for damper control. This system is developed based on the ADDIE model which includes five phases which consist of analysis, design, development, implementation, and evaluate. This product is perfectly developed through technical analysis based on the temperature taken for each angle of the damper opening. This study has shown that the larger the opening angle of the damper, the faster the temperature drops in the testing room. This product has also been confirmed by three experts with experience in the field of refrigeration and air conditioning. The expert was given a questionnaire to obtain data in the design analysis, development and functionality of the product. Based on the results of the design analysis, All respondents agreed that the design produced is easy to understand and attractive. While for the results of the development there is a panel concerns on safety on power usage and suggest to use power supply (AC-DC) but the overall product has also done well based on the sketches made. Finally, the functionality of the product is suitable to be used as an ABBM with improvement comment to enlarge the Liquid Crystal Dispaly (LCD) user interface to make more visible and user friendly. The hope for the product produced is to be able to make this product a teaching aid to help students understand during the PdP process.

1. Introduction

Malaysia experiences hot temperatures reaching up to 37°C (Yip Weng Sang, 2016), causing discomfort and potential health issues. To overcome this issue, air conditioning systems are crucial for creating comfortable and healthy indoor environments. Ideally, indoor temperatures should range between 22°C to 25°C (KW, K. D., & Noviardi, 2015) or follow ASHRAE Standard 55 (2021) recommendations of 73 to 79°F (22.8 to 26.1°C) in summer and 68 to 74.5°F (20 to 23.6°C) in winter. Air conditioning systems, also known as HVAC (Heating, Ventilation, and Air Conditioning), regulate temperature, humidity, and air quality in various settings like homes, offices, or commercial spaces.

Domestic air conditioning systems cater to smaller spaces like houses and apartments, offering cooling, heating, and filtration. It's has been design as smaller cooling capacity and the unit is cost-effective, but it has limitations for bigger room size and model suitability. Types include window units, portable units, and split systems. Commercial air conditioning, on the other hand, serves larger areas like shopping malls, mosques, and office buildings, requiring higher horsepower and extensive cooling capacities. Commercial systems employ techniques like water and air cooling, often using central air conditioning or variable refrigerant flow (VRF) systems for efficient temperature control.

Controlling airflow in commercial HVAC systems involves dampers, which regulate air intake based on desired temperatures. Manual and automatic dampers serve this purpose, with various types such as iris, louver, gravity, Guillotine, Butterfly, and Blast gate dampers, as well as motorized, zone, Backdraft, and fire dampers, each designed for specific functionalities (Gavin, H. P. 2001).

For vocational education students specializing in refrigeration and air conditioning, a deeper understanding of air conditioning systems is crucial. Practical learning aided by teaching tools like models, textbooks, and computers enhances comprehension and engagement. Teaching aids facilitate interactive and clear learning experiences, promoting a better understanding of air conditioning principles and safety features (Ordu, U. B. A. 2021). Understanding the differences between domestic and commercial systems is also essential. Domestic air conditioning systems are designed for individual homes, focusing on cooling or heating single rooms or small areas. They are simpler and have lower capacity compared to commercial systems, which are engineered for larger buildings and diverse purposes. Commercial systems are more complex, serving various activities and requiring advanced control options for precise temperature regulation. Maintenance for domestic systems is simpler and can be done by homeowners or local technicians, while commercial systems require specialized service by professional technicians due to their scale and complexity (Raj, A., & Soni, N. 2017).

In conclusion, the use of teaching aids is essential for comprehensive learning in air conditioning studies. These aids provide insights into air conditioning concepts and operational principles interactively, fostering better understanding among students. Through effective use of teaching aids, students grasp the significance of air conditioning in maintaining indoor comfort, cleanliness, and air quality.

HVAC	Heating Ventilation Air Conditioning
AHU	Air Handling Unit
ADDIE	Analysis, Design, Development, Implementation, Evaluation
VAK	Visual, Auditory, and Kinesthetic
ABBM	*Alat Bahan Bantu Mengajar*
PdP	*Pengajaran danPembelajaran*

1.1 Problem Background

Students encompass various categories beyond just children or teenagers, including adults pursuing education formally or informally. Learning styles can be done in different approaches but one of the most common and widely applied in education is Visual, Auditory, and Kinesthetic (VAK). This approach is a sensory modulation way that combines observation, hearing, and hands-on. Most young students are kinesthetic learners while Visual and auditory preferences emerge later (Sreenidhi, 2017).

Students inclined toward theoretical learning may rely on notes and teachers. Conversely, those inclined towards practical learning require hands-on materials or models to comprehend concepts better. Therefore, to facilitate student learning, teaching aids like models or tangible materials are necessary (Nurin Syahirah, 2017). These aids are defined as instructional aids (ABBM).

In the context of refrigeration and air conditioning students, who are more inclined towards practical learning, tangible materials are crucial (Laila, 2020). After learning sessions, these students will work as air conditioning operators, needing to install, use, and service air conditioning units. Hence, they must master air conditioning concepts during their learning sessions. However, teaching methods for automatic damper control in duct systems are lacking, and learning sessions often rely on slides, which may not engage students effectively.

The lack of suitable teaching models hinders students' ability to understand the principles, importance, and usage of automatic damper control in duct systems (Balqis, 2019). Students face difficulties in learning and mastering this aspect effectively. Explanations about the movement and operation of automatic dampers are often complex and challenging for students to grasp, impacting their ability to design and operate such systems. Thus, a more detailed, understandable explanation with practical examples is needed to enhance students' comprehension.

There was a past study conducted, among which was the design and development of a damper control device for an Air Handling Unit (AHU) based on the Internet of Things (IoT) (Muhammad Nurul Faiz, 2019). The researcher created a model of a damper control device for the AHU system using IoT control. However, the model produced was small, only demonstrating an airflow system controlled using a smartphone. Furthermore, the researcher only developed a closed-loop damper control system that operates only when manually controlled by the user and does not automatically adjust based on the predetermined comfortable temperature.

By identifying and addressing these challenges, this project aims to improve students' learning and understanding of automatic damper control systems. Additionally, the project seeks to simplify explanations and enhance understanding of the movement and operation of automatic damper control. Ultimately, it aims to enhance students' abilities in designing, constructing, and operating efficient and effective duct systems using automatic damper control.

The research objectives for this study are as follows:

1. Designing a duct system with damper control using CAD software.
2. Developing a duct system with damper embedded with manual and automatic control.
3. Testing and analyzing the functionality of the instructional aid ABBM duct system with automatic and manual damper control.

2. Methodology

Research methodology is crucial in project development to ensure that research objectives are achieved. This section elaborates on the steps and methods used to conduct the study systematically and orderly. Methodology involves managing data to address various research questions, including hypotheses (Yahaya, 2006). It also outlines the approach for studying the research framework, sample selection, research instruments, data analysis, and research assumptions (Ghafar, 2003). Ultimately, employing the right methodological approach in project development ensures the successful achievement of the objectives.

To ensure effective research execution, the researcher has adopted the ADDIE model as the design model. By using this model, the project development journey becomes more structured, and each step can be clearly explained. Each letter in ADDIE represents a significant aspect: A stands for analysis, D for design, D for development, I for implementation, and finally, E for evaluation. By following these five steps, a well-organized and quality product can be produced. The use of the ADDIE model in education is essential because it provides a structured approach to instructional design, allowing educators to customize learning experiences based on thorough analysis, efficiently allocate resources, maintain flexibility for iteration, and ensure quality assurance through evaluation (Syuhada, 2018).

2.1 Analysis Phase

This phase is aimed to identify and address issues found in previous studies related to the product, to enhance it. Through analysis, the root causes and factors contributing to the identified issues can be effectively determined. References used for this study include internet sources, journals, books, theses, and insights from relevant experts. This phase needs to be conducted initially to gather information related to the development of automatic damper control for learning and teaching purposes.

The analysis conducted by the researcher involves examining previous studies related to the researcher's course in refrigeration and air conditioning. Specifically, the researcher reviewed a journal titled "Design and development of damper control device for Air Handling Unit based on IoT" (Faiz, 2019). During the analysis, the researcher identified several areas for improvement in terms of functionality and design efficiency. Ultimately, the researcher chose to develop an instructional aid related to the refrigeration and air conditioning course. The researcher found that learning about duct systems mainly relied on theory, lacking practical models for learning. Consequently, students studying duct systems, especially automatic damper devices, could not observe the system's processes firsthand or engage in practical exercises. Therefore, the researcher has established an overall project flow based on the ADDIE model, as depicted in Figure 1, to serve as a reference for creating the desired product.

Figure 1: ADDIE overall project flow

2.2 Design Phase

In the design phase, the researcher will provide more detailed explanations regarding the design and initial sketches of a product according to the suitability of an instructional aid. Therefore, the researcher has made sketches regarding the design ideas of the product and discussions.

For the development of this product, careful consideration of the initial duct airflow direction is pivotal, as it directly influences the airflow dynamics upon entry into a room, with friction within the duct playing a significant role. In this developmental phase, three distinct duct airflow directions have been sketched, each incorporating enhancements aimed at optimizing the airflow speed into the targeted room for cooling purposes. Figures 2 (a), (b), and (c) provide detailed discussions on these design concepts, with a specific focus on aligning them with the educational objectives identified during the Analysis Phase. By examining and comparing these different duct airflow designs, learners gain valuable insights into the functioning of air handling units. This exploration allows them to comprehend how variations in airflow direction impact the efficiency of cooling mechanisms and the uniform distribution of conditioned air throughout an enclosed space. Through this hands-on approach, students not only enhance their theoretical understanding but also develop practical skills in designing systems for effective air conditioning.

(a) **(b)**

(c)

Figure 2 *Design proposal (a) Model Idea 1 (b) Model Idea 2 (c) Model Idea 3*

Table 1 shows the comparison between 3 types of duct airflow directions to be used, and each duct airflow direction has its own criteria and improvements regarding the altered direction.

Table 1 *Comparison of air duct airflow*

Criteria	Idea 1	Idea 2	Idea 3
Duct direction	1 direction	2 directions	1 direction
Friction	Minimum	Slight	Slight
Energy loss	Minimum	Occurs	Occurs
Exit velocity	Fast	Moderate	Moderate
Cost	Less	Requires two elbows	Requires two elbows
Design concept to real model as ABBM	Not appropriate	Not appropriate	Appropriate

Based on ideas one, two, and three, a comparison has been made based on each given criterion. The results of the comparison indicate that the direction of the duct airflow is an important aspect for achieving a good and fast exit velocity. However, the original objective for developing the model as an instructional aid tool needs to be prioritized. In this aspect, emphasis should be placed on suitability based on the real model and understandable to students. Therefore, the chosen design idea is to use concept idea 3. Based on the actual concept of air duct systems, the Air Handling Unit (AHU) serves as the main component responsible for distributing cold air, which it delivers to the desired rooms through the air ducts (Hafizan, 2009). Therefore, the AHU should be positioned at the end of the air duct, and automatic dampers should be placed before entering each desired room. Due to the relatively small size of the produced product, only the actual positioning concept is adopted.

a) Block diagram

A block diagram is a clear and concise depiction of the structure and function of a system. It uses blocks as components and arrows as flows for the system. A block diagram also facilitates understanding of how the system operates and the relationships among its components (Guo, 2007). From a block diagram, one can also efficiently plan, analyze, and improve systems.

For an automatic damper control system, the block diagram illustrates the main components used in the system. Key components include the control, represented by Arduino, the actuator, represented by the servo motor damper, and the temperature sensor. Each component is depicted by a block, and arrows represent the flow within the system. Figure 3 shows the block diagram for the automatic damper control device, while Figure 4 displays the block diagram for the manual damper control device.

Figure 3: Block diagram of an automatic damper control device

When the user sets the temperature to 23°C, the control ensures the room matches this temperature. It sends a signal to the servo motor, which adjusts the damper blades to regulate the air to 23°C. The temperature sensor monitors the room temperature. If it rises to 26°C, the control instructs the servo motor to open the damper by 90°. The temperature is checked again. If it's within the 23°C tolerance, the process is complete. If not, the control continues adjusting until the desired temperature is reached.

Figure 4: displays the block diagram for the manual damper control device.

The manual block diagram represents an open-loop system with one input and one output. When the user sets a temperature of 25°C, the input signal activates the manual circuit. The circuit includes two push buttons: one to open the damper if the temperature is above 25°C and the other to close it if the temperature is below 25°C. The signal then controls the servo motor to adjust the damper blade accordingly. The room temperature detector monitors the temperature, and the output signal is generated accordingly.

b) Drawing design

During the initial stages of product production, a sketch or drawing is created to outline the desired design of the product. This serves as a blueprint, providing a clear vision and ensuring that the final product aligns accurately with the intended shape and size. Additionally, Tinkercad, a user-friendly online platform for 3D modeling, is utilized for creating design drafts. Tinkercad offers various tools and features that enable designers to visualize the final product in a digital environment, allowing for adjustments and modifications to be made before proceeding with physical prototyping.

Figure 5: Product design

2.3 Development Phase

During the Development Phase, the researcher creates the product according to the detailed design and specifications using appropriate equipment. Product development involves turning design sketches into tangible products, ensuring all measurements and component arrangements are accurate. Additionally, the development process includes applying necessary software and wiring for each equipment component.
The diagram for this development phase is to make it easier to understand a system by using block that represent a component in a circuit on figure 6.

Figure 6: Block diagram of two circuits which are manual and automatic

Based on the drawings that have been produced, it has passed the design phase and the next phase is the development phase, this project is produced through several categories including circuit connection and programming, acrylic board cutting, 3D printing, joining products and finishing. Figure 7 shows the finished product that has been made.

Figure 7: Finished product

2.4 Implementation Phase

In the Implementation Phase, the researcher tests the developed product in an air-conditioned room which is has a cool environment. The reason why the room had been chosen due that the refrigerant cycle model is not equipped with the ABBM and the test should be done in an air-conditioned room. The testing mainly focuses on the functionality temperature control of the model and the duration takes to reach the desired temperature in the controller. This is ensuring that the pilot process aligns with the predefined objectives. This study aims to develop an automatic damper control device for educational purposes. Pilot tests were conducted in a room with a stable temperature of approximately 26°C. Two main sets of data were collected: manual temperature changes recorded at various damper angles from 90° to 10° at every 10-minute interval within an hour, and automatic temperature changes observed in the morning and evening, with data collected every 10 minutes for an hour in each session to evaluate the device's functionality. Data were collected through a control box display coded using Arduino, along with a servo motor to move the damper blade and a temperature sensor to detect temperature changes.

This study ensures that the damper control device operates effectively as intended. Data collection involves monitoring temperature changes at different damper angles over time. Automatic testing occurs twice daily, with temperature recordings taken every 10 minutes for an hour during each session. The reason behind this is the researcher uses room temperature or air environment as a cooling material, therefore longer time is needed to collect the data to observe the pattern of temperature change over time. Room temperature is influenced by the external environment and temperature, with morning temperatures being cooler compared to warmer afternoon temperatures (Zulaikha, 2023). Therefore, achieving a comfortable temperature of 23°C in the morning happens faster than in the afternoon.

This testing aims to demonstrate to students that using automatic dampers can maintain a room's temperature within a comfortable range for humans, neither too cold nor too hot. Additionally, in real-world applications, such systems ensure consistent cubic feet per minute (CFM) for each room, reducing excessive energy usage and consequently saving electricity (Atiq, 2020). However, for this product, the primary focus is to prove that the automatic damper functions effectively in achieving a comfortable temperature.

2.5 Evaluation Phase

The final phase of product development involves evaluation by supervisors and researchers to assess functionality and usability. Experts in the field of Refrigeration and Air Conditioning evaluate the automatic damper control product for ABBM in terms of design, model development, and functionality. This assessment ensures the product's readiness for ABBM use and identifies areas for improvement. The evaluation process includes the following steps:

1. Testing the ABBM by at least 3 experts using a prepared questionnaire. The experts selected include lecturers from FPTV, assistant engineers from FPTV, and an engineer from Tripic Medical Sdn. Bhd (FEMS).
2. Verifying the questionnaire language and content before distribution to ensure relevance by the language expert teacher.
3. Analyzing data obtained from the questionnaire responses, recording expert suggestions, and discussing them with the supervisor. Issues and suggestions are addressed in the data analysis section.
4. Using the questionnaire to collect data related to the product's development to ensure research accuracy. The questionnaire comprises four parts: A, B, C, and D, as outlined in Table 2

Table 2 *Items in the questionnaire*

Section	Target
Section A	Demographics
Section B	Suitability of design
Section C	Product development
Section D	Product functionality

3. Results and Discussion

Technical analysis is performed on two main data, the first is the temperature change taken for each angle of the damper opening manually. Second is the temperature change that is taken automatically in the morning and in the evening. Each data taken takes every 10 minutes within 1 hour. The data taken is a way to test the functionality of the product produced.

3.1 Data Collection on Manual Control

The manually collected data on damper opening angles serves the purpose of analyzing the duration and resulting temperature within the testing room, facilitating the development of an automatic damper system aligned with specific temperature requirements. Table 3 presents a comprehensive overview of damper blade openings corresponding to various angles, while Figure 8 illustrates the complete dataset associated with each damper opening angle.

Table 3 *Items in the questionnaire*

Degree	90°	80°	70°	60°	50°	40°	30°	20°	10°
Time	Temp °C	Temp °C	Temp °C	Temp °C	Temp °C	Temp °C	Temp °C	Temp °C	Temp °C

10 min	26	26	26	26	26	26	26	26	26
20 min	25	25	25	25	26	26	26	26	26
30 min	24	25	25	25	25	25	25	26	26
40 min	24	24	24	24	25	25	25	25	25
50 min	23	23	24	24	24	24	25	25	25
60 min	23	23	23	23	24	24	24	25	25

Figure 8: Data from manual control

The analysis based on Table 3 and Figure 8 reveals a clear trend: damper opening angles of 90° and 80° achieve a comfortable temperature of 23°C within 50 minutes, while angles of 70° and 60° require 1 hour to reach the same temperature. Conversely, at angles of 50°, 40°, and 30°, the temperature only reaches 24°C within 1 hour, and at 20° and 10°, it only reaches 25°C within the same timeframe, failing to attain a comfortable level. This technical examination suggests a hypothesis: larger damper openings lead to faster temperature reduction due to increased air volume flow through the room, thus lowering the temperature in the testing environment. However, it also depends on the timing of data collection. This is because the analysis was conducted using ambient air inside a workshop as a cooling tool. The condition of the room is standard to ASHRAE-55 which operates at a temperature comfort level between 22.5°C - 26°C, so data collection in the morning and afternoon might produce different results. Therefore, the researcher collected all data at one time, specifically in the morning, and expected the temperature control would be faster and easier to reach the set point temperature.

3.2 Data Collection on Automatic Control

The data collection on automatic damper blade openings serves the purpose of evaluating the effectiveness of the programmed Arduino system in achieving and sustaining a comfortable temperature of 23 degrees Celsius, as outlined by Zulaikha Zuhairi (2023). Data is meticulously gathered both in the morning and evening at 10-minute intervals over the course of an hour, recognizing the variance in heat generation during these periods. This methodological approach aims to validate the damper's automatic functionality in regulating the temperature of the testing environment. The following is Table 4 for data collection in the morning and Table 5 for data collection in the evening.

Table 4 *Data collection in the morning*

Time	Temperature °C	Degree °
8.00 am	25	80
8.10 am	25	80
8.20 am	24	70
8.30 am	24	70
8.40 am	23	60
8.50 am	23	60
9.00 am	23	60

Figure 9: Graph data in morning

Table 5 *Data collection in the evening*

Time	Temperature °C	Degree °
2.00 pm	26	90
2.10 pm	26	90
2.20 pm	25	80
2.30 pm	25	80
2.40 pm	24	70
2.50 pm	24	70
3.00 pm	23	60

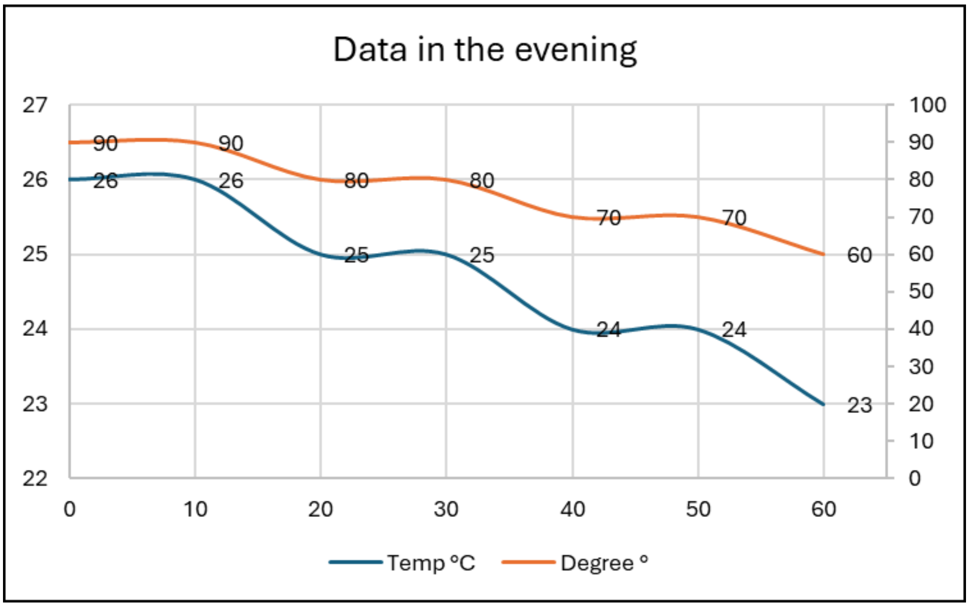

Figure 10: Graph data in the evening

The analysis of data from tables 4 and 5, supported by graphs in figures 9 and 10, confirms the functionality of the product. It automatically reaches and maintains a comfortable temperature of 23°C. In the morning, the room reaches 23°C in 40 minutes, while in the evening, it takes 60 minutes. The 20-minute difference is attributed to environmental temperature variation.

3.3 Evaluation of Experts

Experts in air conditioning and refrigeration were chosen to evaluate the ABBM for the air duct system with damper control. The researcher ensured that the questionnaire language and content were verified before the assessment. Feedback from experts, including FPTV lecturers, FPTV assistant engineers, and engineers from Tripic Medical Sdn.Bhd (FEMS), was collected through evaluation forms. Their input, focusing on product design, development, and functionality, was analyzed for further improvement. On-site experts received face-to-face presentations, while external experts reviewed evidence through recorded video. All comments and suggestions were documented for consideration.

Figure 11: Design survey analysis

Figure 11 shows the analysis that has been carried out based on 8 questions related to product design for the air duct system with damper control. The questions covered real-based design concepts, portability, safety, and user-friendliness as ABBM. As a result of the analysis from the respondents, all the respondents have agreed on the questions that have been given. Therefore, the design of the researcher's product is to meet the suitability of the respondents.

Figure 12: Product development survey analysis

Figure 12 illustrates the analysis of product development. Most of the respondents agree that the product development aligns with the creation of an ABBM. However, one respondent suggested adding components, particularly enhancing the power supply to safely convert from AC to DC.

Figure 13: Product functionality survey analysis

In Figure 13, the analysis of the functionality of the air duct model with damper control as ABBM is depicted. Most respondents agree that the products effectively serve as teaching aids in classrooms. However, one expert disagreed regarding the capability of the board screen and damper opening angle to promote the VAK learning style (visual, auditory, and kinesthetic). The expert noted that the relatively small display screen might hinder its effectiveness in promoting VAK learning styles. Nonetheless, the product's overall functionality has gained approval from most of the experts, indicating its potential to engage students in the classroom.

3.4 Discussions

The analysis of data indicates that three experienced experts in air conditioning and refrigeration found the design, development, and functionality of the ABBM to be appropriate, aligning with the research questions posed. The questions, focusing on the design, development, and functionality of the air duct system with damper control, are crucial in achieving research objectives. While the analysis yielded high agreement percentages, the researcher acknowledges product weaknesses and areas for improvement, as this contributes to project enhancement. Expert feedback highlights areas requiring refinement in the developed products.

3.4.1 Air Duct System Design for Damper Control

The research objectives and questions work together to ensure the development of a quality product. The first objective focuses on designing an air duct system for automatic damper control, with the corresponding research question being "How to design an air duct system for damper control?" Several key elements, including functionality, operation, shape, durability, and user suitability, guide the design process. The researcher utilizes tools such as a wheeled iron base and acrylic materials to create a sturdy and user-friendly product. Expert evaluation, including FPTV senior lecturers, assistant engineers, and industry technicians, confirms the suitability of the design for classroom use, aligning with the research objective and addressing the first research question. Based on the produced project, it has been demonstrated that improvements have been made compared to previous studies. The resulting product is larger, and the damper opening control is automated according to the comfortable temperature. Additionally, it is easier to understand and more practical to use as a teaching aid in the classroom.

3.4.2 Develop an Air Duct System for Damper Control

The development of an air duct system for damper control aligns with the need for engaging teaching aids in classrooms, as noted by Muhammad Hazriq (2019). Following the ADDIE model's phases of analysis, design, development, implementation, and evaluation, the researcher undertook various tasks, including circuit connection, Arduino programming, acrylic board assembly, 3D sketching, and 3D printing. Challenges such as cost, material sourcing, and time constraints were encountered during development, requiring resourcefulness and patience. The researcher decided to use recycled material from other unused products to develop the ABBM and it saved about 70% of the total initial cost. is Expert confirmation on the system's development largely approved its suitability as an ABBM by the question on section C, although one expert suggested enhancing the power supply component for safety. Power supply is a fundamental equipment in an electronic system to regulate the unregulated power and converting into stable direct current (DC) supply (Adelakun, 2014). Thus it promotes a safer situation and protects users from electric shock. Despite this, the product met the criteria for effective development, fulfilling the second objective.

3.4.3 ABBM functionality of air duct system with damper control

The functionality analysis of the air duct system with damper control, referred to as ABBM, includes manual and automatic data collection to assess temperature control. The product aims to regulate room temperature by adjusting the damper angle, inspired by more advanced real devices. Manual data collection occurs every 10 minutes over an hour, while automatic analysis adjusts the damper to reach a comfortable 23°C. Experts confirm the product's effectiveness for the teaching process, although one suggests improving the display screen for better visual learning. Learning style is the manner or fashion how someone acquires, attains, retains, and uses imagination to attain skills or information (Hussain, 2017). The bigger display will attract visual learners to explore more and easily get some information and writing down. Some parts of the ABBM like the damper cannot be seen through using naked eye because of the construction of its body made from non-transparent material, the display is much helps learners to imagine how the rotation degree of the damper correlates to temperature varying. Overall, the product meets its objective of facilitating the teaching process, fulfilling the third objective.

3.5 Suggestion

Experts suggest several improvements for the air duct system with damper control. Firstly, integrating power sources into a single output with a fuse can enhance safety and stabilize the current flow to the Arduino board. Enlarging the display screen on the control box can aid in better readability and facilitate VAK learning styles among students. Future enhancements include incorporating a basic refrigeration cycle to improve cooling efficiency, integrating an IoT system for remote operation, and adding automatic temperature control input for greater versatility. These suggestions aim to enhance the product's functionality and usability, benefiting future learners interested in air duct systems with damper control.

3.5.1 Power Supply

Make additions in terms of a more efficient power supply where it is necessary to combine all the required power sources and provide a power supply output using a socket equipped with a fuse. This can prevent any occurrence of short circuits to the components, thus improving the safety aspect of the use of air duct system products with damper control. According to experts, by using a switching power supply, the current provided to the Arduino board is more stable because the component has a transformer that can adjust the current as needed. Therefore, electrical goods can be preserved, thereby extending the life of the product (Hasif, 2015).

3.5.2 Enlarge The Display

An improvement that can be made in the future is to enlarge the display screen in the control box. This is necessary to address question D7, which concerns the display screen and damper opening angle that can facilitate VAK learning styles (visual, auditory, and kinesthetic) among students. Currently, it is not very effective because students find it difficult to read the text displayed on the screen to obtain temperature readings and the angle of the damper opening. According to Farah Nadiah (2017), 40% of students are more inclined towards visual learning styles, where a student who is proficient in using images usually remembers faces better, enjoys developing ideas, thinks in terms of pictures, and finds it easy to visualize various objects in their mind. Therefore, it is important to have a large display so that students can easily see and understand the content.

3.5.3 Basic Refrigeration Cycle

The proposal involves adding a genuine basic refrigeration cycle to the product, which comprises four main components in the cooling system: compressor, evaporator, condenser, and expansion valve (Fazreen, 2018). This proposal arises because the original product only uses ambient air as a cooling agent to cool the testing room. Therefore, with the addition of a basic refrigeration cycle, the efficiency of air temperature control can be improved more effectively. This change aims to optimize the cooling process and achieve more precise temperature control within the testing environment.

3.5.4 Internet of Thing (IoT)

Enhancing the IoT system incorporated into the product. According to Faiz (2019), IoT is a system that enables the product to function effectively over long distances, potentially improving its usability and accessibility. By implementing such improvements, students would have the opportunity to engage with the product's functionalities remotely. This hands-on experience would enable them to understand the complexities of the

ABBM system more comprehensively, simulating real-world scenarios where larger, clearer interfaces are often encountered. Overall, these enhancements aim to enrich the learning experience by providing students with practical exposure to advanced technological systems.

3.5.5 Temperature Control Setting

Enhancing the system by integrating a feature that allows users to input their desired temperature settings. This improvement should include an automatic control mechanism to regulate the temperature accordingly. Currently, the system relies solely on a default temperature of 23°C, which may not always align with individual preferences or environmental conditions (Ridzuan, 2019). By incorporating customizable temperature settings and automatic control, users can enjoy a more tailored and efficient experience, ensuring optimal comfort levels while minimizing energy consumption.

4.0 Conclusion

In conclusion, the research successfully achieved its objectives of designing, developing, and testing the ABBM for the air duct system with damper control. The product, crafted with meticulous attention to detail, serves as a valuable teaching aid for classroom sessions in refrigeration and air conditioning studies. The availability of this product enhances students' understanding of AHU units and automatic damper operations. A user manual accompanies the product to facilitate easy usage during teaching sessions. The product's visually appealing design and room-like interior decoration captivate students' interest, making complex concepts more accessible. With validation from experienced experts, the product stands poised to enrich learning experiences in the classroom.

Acknowledgement

The authors would like to thank University Tun Hussein Onn Malaysia (UTHM) for facility support in this research.

References

Abang Rasfiezan Bin Abang Ibrahim. (2017). Simulator kitaran asas sistem peti sejuk sebagai bahan bantu mengajar

Ahmad Izzuddin Bin Zahidan. (2022). Smart learning wiring board with IOT sistem (SLWB)

Atiq Saifullah Bin Lokman Hakim (2020), Air distribution analysis on the adjustable *damper* for air conditioning system

Atiq Saifullah Bin lokman Hakim. (2020). Air distribution analysis on the adjustable *damper* for air conditioning system

Awang Hafizan Awang Jakarian. (2009). Building information modeling bagi mereka bentuk kerja sesalur sistem penyaman udara

Balqis Binti Zahari. (2019). Sistem menara pendingin sebagai ABBM untuk program teknologi penyejukbekuan dan penyamanan udara di Kolej Vokasional.

Chan Ho Chun. (2017). Environment monitoring system using *arduino* and android smartphone

Farah Syazwiena Abd Sukor. (2017). Ststem pengurusan tajuk projek sarjana muda UTHM

Fu, Y., O'Neill, Z., Wen, J., Pertzborn, A., & Bushby, S. T. (2022). Utilizing commercial heating, ventilating, and air conditioning systems to provide grid services: A review. Applied Energy.

Guo, H., & Yang, X. (2007). A simple reliability block diagram method for safety integrity verification. Reliability Engineering & System Safety

Hafid, A. (2011). Sumber dan media pembelajaran. Sulesana: Jurnal wawasan keislaman.

Hamdan, A. R., & Mohd Yasin, H. (2010). Penggunaan alat bantu mengajar (ABM) di kalangan guru-guru teknikal di Sekolah Menengah Teknik Daerah Johor Bahru, Johor. Penggunaan Alat Bantu Mengajar (ABM) Di Kalangan Guru-Guru Teknikal Di Sekolah Menengah Teknik Daerah Johor Bahru, Johor, 1-8.

KW, K. D., & Noviardi, Z. (2015, July). Penerapan inferensi fuzzy untuk kendali suhu ruangan pada pendingin ruangan (AC). In Seminar Nasional Informatika.

Lambri, A., & Mahamood, Z. (2019). Penggunaan alat bantu mengajar dalam pengajaran bahasa Melayu menggunakan pendekatan pembelajaran berpusatkan pelajar. International Journal of Education, Psychology and Counseling.

Markusson, C. (2011). Efficiency of building related pump and fan operation (Doctoral dissertation, Chalmers Tekniska Hogskola (Sweden)).

Maxtone andres. (2023). Sistem sanitasi berasaskan iot pada unit pisah dengan mengitar semula air kondensasi penyaman udara

Md Azhan Bin Mohd Idris. (2023, Januari 19). Papan pemeran. https://saidina.com.my/product/economy-display-panel/

Moesby, E. (2004). Reflections on making a change towards Project Oriented and Problem-Based Learning (POPBL). World transactions on engineering and technology education, 3(2), 269-278.

Mohamad Amirudden Bin Mohd Tahir. (2017). *Servo motor* speed control with *arduino* and MATLAB/SIMULINK

Zulaikha Binti Zuhairi. (2023). The influence of air damper toward the air balancing system and thermal performance of centralized air conditioning system.

Adelakun Adedayo Oke,Rabiu Jamiu.Ariyo, Egunjobi Abiodun Isiaka, Akinnubi Rufus Timotheu (2014). Design and Construction of a Stabilize Variable Power Supply Unit. Innovative Systems Design and Engineering. ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online) Vol.5, No.6, 2014.

Hussain, I. (2017). Pedagogical implications of VARK model of learning. University of Lahore,Pakistan, Department of English Linguistics, p.33. Retrieved from http://www.researchgate.net/Pedagogical_Implications_of_VARK_Model_of_Learning

Mr. Sreenidhi S K, Ms. Tay Chinyi Helena (2017). Styles of Learning Based on the Research of Fernald, Keller, Orton,Gillingham, Stillman , Montessori and Neil D Fleming. International Journal For Innovative Research in Multidisciplinary Field. Volume - 3, Issue - 4, Apr - 2017