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# Comprehensive Simulation of Adjustable Welding Jig through ASIE Model in Refrigeration and Air Conditioning Workshop

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## ABSTRACT

*Welding job involves a number of different tools and it is very common to use welding jigs on a project due to their strength and dependability. However, most of the welders used only brick, cast iron or G clamp for welding purposes that can be very risky and ineffective as the welding workpiece needs to be tightly secured because welding work can be very dangerous if the workpiece falls, despite the lowering of the welding accuracy. Thus, the objectives of this study are to design and develop a simulation for adjustable welding jigs through ASIE model application in refrigeration and air conditioning workshop and test its functionality using the Technology Acceptance Model (TAM). The design and development process through the ASIE model consists of four phases, namely analysis, strategy, implementation and evaluation. This study used a design and development (DDR) research design that involved quantitative data in which the experts in the welding industry assess the product's functionality through questionnaires. The population and sampling were selected randomly through the purposive sampling method in order to determine the respondents of the study. Overall, the documented experts' evaluation explains the strengths and advantages in the design of the product. In addition, these adjustable welding jigs have made welding jobs easier, quicker, more accurate, comfortable and cost-efficient.*

**Keywords:** adjustable welding jigs, ASIE model, Technology Acceptance Model (TAM)

## 1. INTRODUCTION

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by using high heat to melt the parts together and allowing them to cool, then fuse (Khan, 2007). Thus, given that there is a rapid growth of organizations nowadays, welding seems to be the primary process. It is also one of the core principles for the design and improvement of metal-based production. Therefore, it is impossible to find any industry, large or small, that does not utilize any welding type or welding equipment. Most industries found that welding is an efficient method that can be performed by manpower or machine that can save time and costs, especially in the handling of metal design (Stig-Börje & Nina, 2020).

Nonetheless, the welding process cannot be carried out efficiently because the workpiece cannot be held properly and firmly while the process is being performed. Therefore, various innovations have been made to promote welding work at different welding positions (Postlethwaite, 2017). There were also various welding courses recently, but the courses often take a long time, high cost, lack of instructors and ineffective welding equipment (Batzler, Albrecht & Becker, 2016). Ineffective equipment causes the teaching or courses to be less efficient, especially when

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demonstrating a cylindrical workpiece like a copper tube. Besides, the main problem faced by teachers and students during the teaching and learning (T&L) process is that it takes a long period to weld because the welding process has to begin with starting point and endpoint before starting to weld the workpiece (Nurfauzi, 2017).

The layout of the vocational education laboratory for welding should accommodate the space for robots and other supporting equipment to support the learning process (Ismara & Prianto, 2020). As such, plasma welding, laser welding, and electron beam welding technologies guarantee the sound quality of welded joints and can be used for air conditioning applications in the automotive industry (Weglowski *et al.*, 2017). Substantial refrigeration and air conditioning services are required to provide the needed and satisfactory repair and maintenance services to support the industry (Baffour-Awuah, 2020). To achieve this, it is important to redesign the learning layout that accommodates anthropometric limitations aiming to enable students to carry out their learning activities that are comfortable, healthy and safe to avoid illness due to its practical work, especially in refrigeration and air conditioning workshop (Ismara & Prianto, 2020).

Zolkepali (2017) stated that many circumstances could cause problems to the educators as they have trouble demonstrating the welding process to the students because no appropriate jig can be used to show all welding positions. A jig is a large brace that keeps a welding project stable under pressure, heat, motion, and force. A quality jig will streamline welding work by keeping parts together in a vice grip. However, educators must first nail the workpiece to the existing jig due to the limitations. This process is a waste of time because it also requires the help of the student. Safety must be considered as the workpiece is simply nailed to the jig, which could cause the workpiece to fall and cause injury to the teachers and students.

According to Yamada (2021), welding works involving pipes and connectors are often not coordinated or standardized because the workpiece is not properly organized. The use of tool handlers during welding work in various connections and existing positions is quite confusing for the students. Therefore, they have to use bricks or cast iron to hold the workpiece. This method is a bit impractical and time-consuming besides dangerous to the welders if the workpiece falls on them, especially if the welding process is cylindrical.

Thus, this study focused on the development of adjustable welding jigs that can promote the work of connecting the copper tube in the air-conditioning field where the jig can support the work of connecting two different tubes in refrigeration and air conditioning workshop. Simultaneously, this will allow the welders to weld quickly and easily at any different positions. This jig was designed to facilitate welding work, particularly in copper pipe welding in the field of air conditioning. It serves as the holder workpiece during the welding process, facilitating and supporting it. The mass production method needs a fast and easy to perform a proper operation on it (Nurfauzi, 2017).

The design and development phase needs to be analyzed and planned to save time and cost. In addition, a detailed study can promote and provide structured and systematic work to achieve the goals of the adjustable welding jigs development. Meanwhile, the methodology process can provide this study with new exposure to the unforeseen and unexpected side effects as well as provide information that can enhance the product to be produced. 21st-Century Learning generates knowledge among teachers of the learning component required to create a more critical and creative learning environment for their students. As such, the design and development process of the adjustable welding jigs in this study tends to address the problems faced by the teacher and students. It is also hoped that this study will help increase the students' interest in this welding field.

ASIE Integral Teaching Design Model is an integrated approach in the process of planning teaching strategies for the needs of students in 21st-century learning and teaching environment. ASIE refers to the process of Analysis, Strategy, Implement, Evaluate and a mechanism known as Multiple Integration Worksheet (MIW) to form an overall instructional planning process. This instructional design model is essential for redesigning, reconstructing and redirecting instructional learning in the context of the current educational landscape to provide students with an opportunity to learn and in the face to thrive the emerging challenges.

According to Zain (2017), the ASIE Model is an innovative teaching design model for teachers to enhance and sustain the standard of 21st-century learning quality. The development of the integral ASIE Model impacts the lesson planning. It is an important model since all components are merged into a Multiple Integration Worksheet (MIW) to form complete teaching and learning profile at the micro-level (Zain & Campus, 2016). Furthermore, the planning carried out competently and professionally was based on the design of teaching theories and principles. Thus, this study plans to design and develop an adjustable welding jig through ASIE model application in welding workshop, based on the advantages that this planning model seems to be interactive user, integrative in content design, prescriptive in procedure planning and constructive in the component organization.

Although the ASIE model has usually been practical and functionally effective in teaching planning and is relevant to the 21st-century learning environment, the enhancement of knowledge and skills and the fostering practices through ASIE steps seems to be suitable as a process in developing the adjustable welding jigs. Thus, this study used an ASIE model modified by eliminating the MIW process to design and develop an adjustable welding jig, as in Figure 1. Welders need more advanced welding tools than simple clamps to ensure that a welding project turns out as intended without flaws or damage.

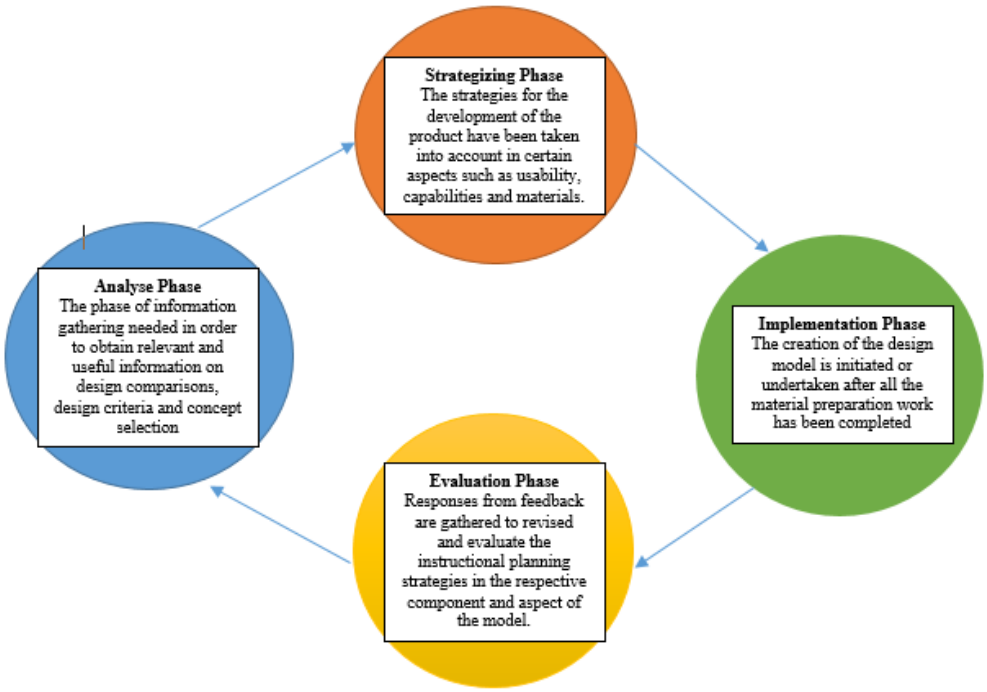



**Figure 1.** Key structure of the Modified ASIE Model.

In every welding job, many circumstances create problems for educators. They have trouble demonstrating the welding process to the students because no appropriate jig can be used to show all welding positions as the existing jig does not cover all welding positions. Currently, most welders use only brick, cast iron or G clamp for welding purposes. However, this approach is risky

and ineffective because the welding workpiece needs to be tightly secured to prevent any dangerous event if the workpiece falls, despite lowering the welding accuracy. Thus, this study sought to design and develop a simulation for an adjustable welding jig through ASIE model application in refrigeration and air conditioning workshop and test its functionality using the Technology Acceptance Model (TAM).

## 2. METHODOLOGY

Research design is a technique or method specifically used to obtain information or data to solve problems. Systematic planning is a neat and well-organized plan vital for smooth preparation in producing a project. Based on the design and development research (DDR) method by Brown and Collin in the 1990s, the adjustable welding jigs were built using a systematic planning system (Richey & Klein, 2014). DDR provides an alternative for systematically carrying out a design, commonly used to test a theory and validate its practicality (Sahrir *et al.*, 2012). It has three main phases, as illustrated in Table 1.

**Table 1** DDR Phases Implementation

| Phase | Types of Development |
|---|---|
| Phase 1: Requirement Analysis | Literature Review |
| Phase 2: Design and Development | Qualitative Method (Semi-structured Interview) |
| Phase 3: Functionality | Quantitative Method (Checklist of Technology Acceptance Model) |

### 2.1 Population and Sampling

A population is a complete set of elements (people or objects) with general characteristics identified by sample criteria to be examined by a researcher. The smaller the population size, the smaller the precision (Chua, 2011). The respondents in this study consisted of educators or teaching staff from the Vocational and Community Colleges around Johor. They involve in welding work, primarily in refrigeration and air conditioning. A sample is intended to reduce the scope and size of the population. This representation should be specified in terms of expertise, experience, or any features to be studied (Chua, 2011).

A simple random sampling method was used, and the units were selected individually and simultaneously via a random process (Chua, 2011). Three experts specialized in teaching refrigeration and air conditioning, particularly welding copper tubes, were chosen as a respondent. However, the research findings through sampling are not representative or descriptive of the population but provide an initial image of the field of study (Fruth *et al*., 2019).

**Table 2** Sample of Respondents

| No. | Respondents | Location | Quantity |
|---|---|---|---|
| Respondent 1 (R1) | Refrigeration and air conditioning field | A | 1 |
| Respondent 2 (R2) | Refrigeration and air conditioning field | B | 1 |
| Respondent 3 (R3) | Refrigeration and air conditioning field | C | 1 |

## 2.2 Data Analysis

Data analysis is defined as the process of analyzing, categorizing, tabulating and integrating evidence or data to address the initial proposal of research. These data are then used to infer, forecast outcomes or endorse study findings. Essentially, data analysis starts with studying raw data and using scattered plots to identify patterns. This pattern is extracted from a theoretical and literature review (Eken, 2020). In this study, questionnaires were developed to evaluate the functionality of the adjustable welding jig products based on the Technology Acceptance Model (TAM) elements. This quantitative research method can be used to perform statistical, mathematical or calculation techniques for the data (Sukamolson, 2007). The instrument used to get the quantitative data has been validated by an expert in the product-based assessment. The percentage value describes the level of acceptance by the respondents related to the questionnaire (Schilling & Neubauer, 2017) and has been given to the respondents as shown in Table 3:

**Table 3** The Evaluation Percentage Level of Expert Validation

| Evaluation Level | Percentage (%) |
|---|---|
| Poor | 0–49.9 |
| Moderate | 50–74.9 |
| High | 75–100 |

## 2.3 Product Design

In order to achieve high-quality research results and meet the objectives of the study, the process must be systematically planned and implemented. The planning phase will minimize or eliminate any unforeseen errors. These adjustable welding jigs were developed based on ASIE Model instructional design as part of the product development process. In this process, four main phases of the ASIE Model method became the guideline for the development of the product:

### *2.3.1 Analyzing Phase*

This information gathering or analyzing phase is needed to obtain relevant and useful information on design comparisons, design criteria and concept selection. This study conducted observations on trainees involved in arc welding work or copper tube connections in schools or education institutions' workshop. Based on the observation, it was found that this workshop mostly does not have a special or good jig to hold the workpiece, in the form of a plate or a tube, especially when connecting the copper tubes to the cooling system and the air conditioning in a workshop. This has made the connection process complicated, dangerous, and ineffective as there is no proper jig or handles specifically built to connect the particular shaped workpiece pads cylinder. Then, the information and details on the matter related to the existing jigs, especially in welding on a plate and cylinder-shaped materials, have been collected. During the design process, five main aspects have been evaluated in designing the adjustable welding jig, as shown in Table 4:

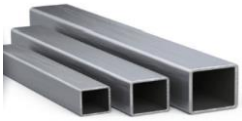
**Table 4** Selection of Design Criteria

| Criteria | Explanation |
|---|---|
| Functionality | This design should have an operational value where the design developed fits or meets the scope of the study, including the safety measures to prevent any accidents occurring during the handling of the adjustable welding jigs |
| Controllability | Consumers need to manage the products guided by manual provided so that the operation of the product system can be shown |
| Design | The development of adjustable welding jig design must be compatible with the functions and operating methods used for teaching and learning purposes in the PPU laboratory |
| Agility | Selection of materials for the development of the adjustable welding jigs through ASIE Model Application in refrigeration and air conditioning workshop must be considered since it also involves the product durability by which the product is ready to be assembled and can function properly |
| Economic | The cost, time and energy of the welding jig design are quite high, but, in reality, it is affordable with its functionality as an effective tool for process welding in the refrigeration and air conditioning workshop |

### *2.3.2 Strategizing Phase*

In this phase, the strategies for developing the adjustable welding jigs considered aspects such as usability, capabilities and materials. Other considered criteria include ergonomic, user-friendly, aesthetically pleasing and easy to maintain. The product selection was based on its size and costs. Table 5 was developed to ease the preparation and planning in researching the main components and consumables.

**Table 5** The Main Components of Adjustable Welding Jig Design

| Main Components | | | |
|---|---|---|---|
| **No.** | **Component** | **Price Per Unit (RM)** | **Quantity (nos)** |
| 1 |  Magnetic Jigs | 15.00 | 4 |
| 2 |  Iron Plate | 30.00 | 1 |
| 3 |  Hollow Iron | 15.00 | 1 |
| 4 |  Elastic Rubber Caster Wheel | 4.00 | 4 |

| | | | |
|---|---|---|---|
| 5 |  Various sizes of bolt | 20.00 | 2 |
| 6 | Paint | 8.00 | 2 |

### *2.3.3 Implementation Phase*

In this phase, the design model creation was initiated after all the materials preparation work had been completed. This process requires a lot of energy and workshop tasks, mostly through the use of machines and equipment. The product's design was drawn from the sketch and finalized using engineering drawing. The design was displayed in 3-dimensional form using computer-assisted drawing, namely Google Sketch Up, to promote the process of developing a product based on the shape and size, as shown in Figures 2, 3, and 4.

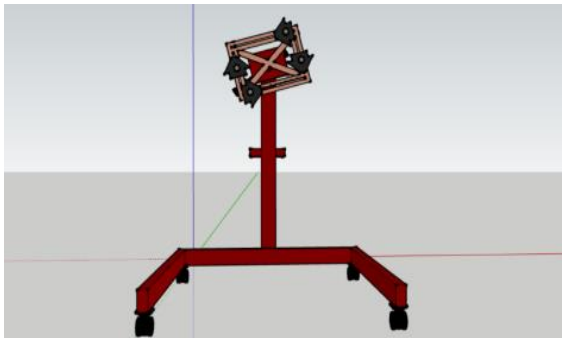


**Figure 2.** Front view.

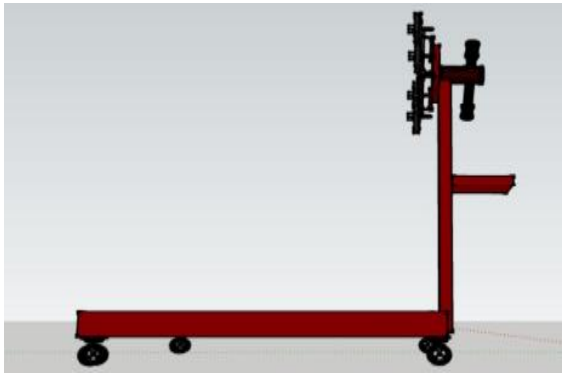


**Figure 3**. Side view

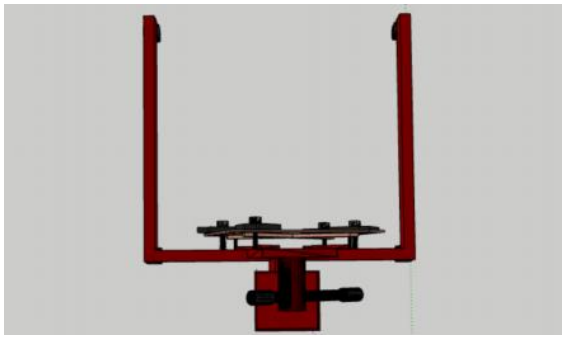
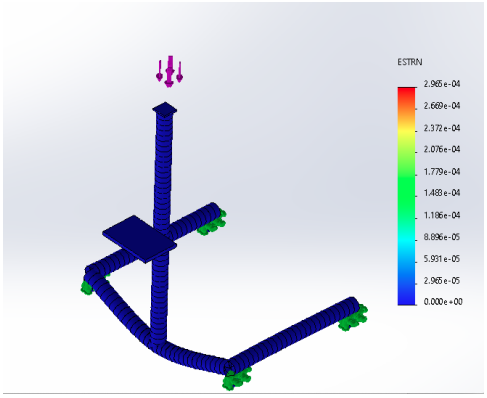
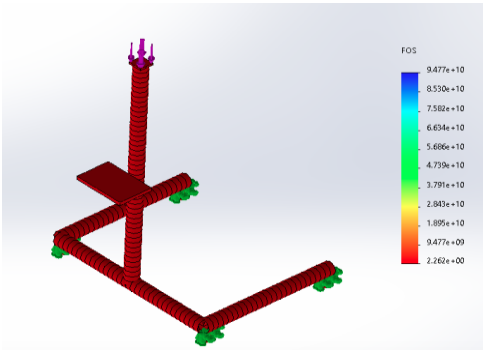
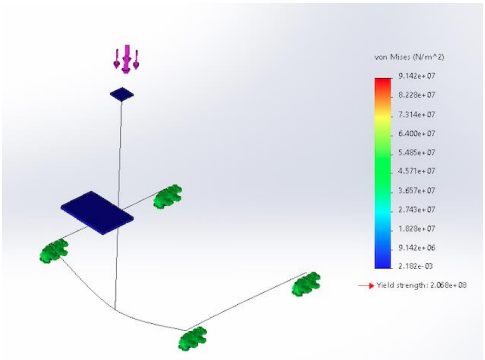


**Figure 4.** Top view.

The finite element analysis (FEA) is a widely used method for numerically solving differential equations arising in engineering and mathematical modeling. Table 6 shows the simulation for FEA to simulate the behavior of a part under in terms of deformation, the safety of factor and von mises2. The FEA process help in simultaneous calculation and visual representation of a wide variety of physical parameters such as stress or temperature, enabling the designer to rapidly analyze performance and possible modifications.

**Table 6** Simulation for Finite Element Analysis (FEA)

| No. | Items | Remarks |
|---|---|---|
| 1 |   | The figure shows the deformation of the product on the vertical force when the force is applied downwards |
| 2 |   | The figure shows the safety factors are within the requirement, which is <0.5. It indicates the product is safe to be used |
| 3 |   | The figure shows the yields strength analysis of the product, indicating the product is in good condition when the force is applied without failure |

### *2.3.4 Evaluation Phase*

The adjustable welding jig was designed to make copper tubing easier and safer for workers, trainers and students, especially in refrigeration and air conditioning workshop. The functionality of this project allows this product to be used successfully and helps welders conduct welding effectively. Despite that, the evaluation process also considers the user's ability to weld using this adjustable welding jig contentedly. The results of both evaluation processes will determine if this adjustable welding jig was functioning well and allow changes or improvements to be made to increase the efficiency of the welding work.

Once the product has been developed, it should be tested and evaluated in terms of product functionality, welding attachment strength, design structure weight, tidiness and materials used to overcome the remnants of existing weaknesses. In addition, the researcher also carried out the experts' verification process after developing the adjustable welding jig products. This product has been tested by the experts using the validation form that has been provided to fulfil the research objectives.

## 3. RESULTS

This part addresses the results of quantitative data gathered from the questionnaire on the functionality of the adjustable welding jig based on feedback from experts in refrigeration and air conditioning. A total of three experts were selected, consisting of educators or teaching staff. Each item from the questionnaire was based on the Technology Acceptance Model (TAM) rubric that includes the perceived usefulness, perceived ease of use, attitude toward using, behavioral intention, and actual use (Davis *et al*., 1989). In addition, expert evaluation is being carried out to explain the strengths and weaknesses found in the product's design.

**Table 7** Perceived Usefulness

| No. | Item | Yes | | No | |
|---|---|---|---|---|---|
| | | Total | % | Total | % |
| 1 | The design of this product improves the efficiency of the welding process. | 3 | 100% | 0 | 0% |
| 2 | The product design does not require a high level of welding skills. | 3 | 100% | 0 | 0% |
| 3 | The design of this product enhances the learning performance of the refrigeration and air conditioning courses. | 3 | 100% | 0 | 0% |

Based on Table 7, all experts agreed on its usefulness aspects and agreed that the product's design increases the effectiveness of the welding process. The second item was analyzed in terms of product design aspects, indicating that it does not require a high level of welding skills as the components and materials were mostly utilized in workshops. Finally, the last item shows that all experts agreed that the design of this product improves the learning performance of refrigeration and air conditioning courses. In conclusion, the result showed that the adjustable welding jig developed by the researcher was in line with the experts' opinion.

**Table 8** Perceived Ease of Use

| No. | Item | Yes | | No | |
|---|---|---|---|---|---|
| | | Total | % | Total | % |
| 1 | The design of this product is simple to use | 3 | 100% | 0 | 0% |
| 2 | The design of this product is portable | 3 | 100% | 0 | 0% |
| 3 | The size of this product is suitable for use in refrigeration and air conditioning workshop | 3 | 100% | 0 | 0% |

Based on Table 8, all experts agreed that the convenience aspect makes it easy to use the product as a facilitator of welding work does not require complex concepts to be understood to handle it. All experts also agreed on the second and third items about the design of this product that can be easily moved anywhere and that this product size is suitable for use in the refrigeration and air conditioning workshop.

**Table 9** Attitude toward Using

| No. | Item | Yes | | No | |
|---|---|---|---|---|---|
| | | **Total** | **%** | **Total** | **%** |
| 1 | The use of this product is important during the pipe tubing process | 3 | 100% | 0 | 0% |
| 2 | This product does not require the use of an electrical energy source | 3 | 100% | 0 | 0% |
| 3 | The safety aspect during welding is guaranteed when this product is used in refrigeration and air conditioning workshop | 2 | 66.6% | 1 | 33.3% |

Table 9 shows that almost all experts agreed on the aspect of attitude towards the use of this product. All experts gave positive feedback on the items asked. The first item was agreed upon by all the experts who claimed that the use of this product was important during copper tube piping. This is because the students often use bricks or cast iron to hold the welding workpiece during the welding work. In addition, all experts agree with the second item that stated this product does not need to use electrical energy sources since this product only uses mechanical systems manually. Finally, the third item of this aspect shows that only two experts agreed that the product was safe to use when welding in the refrigeration and air conditioning workshop, while another expert distressed as the product had sharp corners that would make the product unsafe if the user accidentally hit it or if the product falls on the user.

**Table 10** Behavioral Intention

| No. | Item | Yes | | No | |
|---|---|---|---|---|---|
| | | **Total** | **%** | **Total** | **%** |
| 1 | The ergonomic aspect of this product is suitable for welding work in refrigeration and air conditioning workshop | 3 | 100% | 0 | 0% |
| 2 | This product is safe to be used by the trainees or students in the refrigeration and air conditioning workshop | 3 | 100% | 0 | 0% |
| 3 | No contamination occurs when this product is used | 3 | 100% | 0 | 0% |

Based on Table 10, all experts agreed on the behavioral element through this product founded by the positive feedback. The first item of this study was agreed upon by all experts who confirmed that the ergonomic aspect of this product is suitable for welding work in refrigeration and air conditioning workshop. This is because the product has adjustable parts suitable for any welding material and the size of the user body. Also, all experts agreed with the second item on the safety of this to be used by teachers or students in the refrigeration and air conditioning workshop. Finally, the third item reveals that all experts agreed that no contamination occurred when this product was used since it does not involve electricity or any motor components.

**Table 11** Actual Use

| No. | Item | Yes | | No | |
|---|---|---|---|---|---|
| | | Total | % | Total | % |
| 1 | This product reduces the time taken for the welding work process | 3 | 100% | 0 | 0% |
| 2 | This product has minimized the workforce during the welding process | 3 | 100% | 0 | 0% |
| 3 | The magnet on the jig makes it easy for the user to put a workpiece on the jig | 3 | 100% | 0 | 0% |

Lastly, Table 11 shows that all experts agreed on the actual use of this product based on their positive feedback. The first item shows that all experts agreed that this product had reduced the time taken for the welding work process. This is because the product can perform the welding work closely and there is a ruler scale on the jig site that will make it easier for the user to measure the work directly and precisely on the jig. Moreover, all experts agreed on the second item stating this product has minimized the workforce during the welding process. This is because the product only needs to be handled by the welder and does not require assistance to support it. Finally, the third item states that all experts agreed that the magnets on the jig have made it easier for the user to put the workpiece on the jig since the welding work position would be better and stronger with the magnet on the jig.

## 4. DISCUSSION

This study aims to design and develop an adjustable welding jig through ASIE model application in refrigeration and air conditioning workshop and test its functionality using the Technology Acceptance Model (TAM). In order to enhance and assist trainers or students in facilitating the welding work in the refrigeration and air conditioning workshop, this adjustable welding jig seems to be the solution for welding activity which was previously a bit difficult without a proper jig. The development of this adjustable welding jig is an effort to facilitate teaching and learning sessions for the teachers and students, particularly in education, as well as expertise in refrigeration and air conditioning. According to Mulyadi *et al*. (2019), the welding jig is one of the supporting equipment required for installation work, especially in the welding process. The designed adjustable welding jig seems to suit its suitability, especially for refrigeration and air conditioning workshop use.

Based on a study conducted by Nurfauzi (2017), a Robot Jig Welder was developed to optimize the time during the T&L session in the manufacturing classroom. The result proved that the jig used contributes less time to the welding process since the jig also facilitates the research and development (R&D) process during the session while running the welding robot process. The welding procedure includes appointment extension through T connection and the mounting connection. These processes were conducted with the aid of welding robots without the need for welders to consider the starting point and endpoint of the workpiece. According to Pandapotan *et al*. (2018), a jig is used to stabilize the welding process and to set the desired dimensions, and speed up or simplify the process of holding the workpiece. Therefore, it is very important for us to take note of the jig quality.

A study by Ordieres *et al*. (2020) on the welding distortion and jig analysis performed shows that the jig design is much more relevant to the welding sequence to mitigate welding distortion within a given manufacturing route. Shrivastava and Shyam (2020) showed that the jig designed through the versatility or the ability of the fixture to weld suspension a-arms of any passenger vehicle in the automobile industry could be used for any passenger vehicle suspension. A-arm

welding has been cost efficient, productive, and safe besides satisfying the welding process's functionality. Furthermore, topology optimization and Laser Powder Bed Fusion for manufacturing welding jigs in automotive body shops also show high material efficiency and weight reduction (Schuh *et al*., 2020).

In order to identify the functionality of the adjustable jig welding through ASIE model application in refrigeration and air conditioning workshop, three experts in the field of refrigeration and air conditioning were chosen as respondents to provide feedback using TAM questionnaires. The results indicate that all experts agreed with the functional aspects posited in the feedback form. This adjustable jig welding can also be used as a teaching aid. Almost all respondents agreed that the jig design is attractive and fully functional. The product design is also practical because it is small enough to easily transport or carry by a user. The TAM questionnaires were selected for this study because, according to Fathema (2015) and Abdullah and Ward (2016), it is the most prominent, widely used and has important characteristics in designing the quality form of the study. According to Rafique *et al*. (2019), the TAM is the most commonly used in e-learning, with the performance of a quantitative meta-analysis. As such, this adjustable jig welding seems to be stationary in the face of the welding tool and able to be moved to follow the weld. A decent jig should have several fixtures, making it possible to weld multiple pieces simultaneously or weld different shapes and metals on the same frame.

## 5. CONCLUSION

In conclusion, the outcome of this study can benefit the teachers, lecturers and students whether in vocational colleges, private institutions or public universities, especially in the field of refrigeration and air conditioning. The study's main objective to design and develop an adjustable welding jig through ASIE model application in refrigeration and air conditioning workshop and test its functionality using the Technology Acceptance Model (TAM) has been achieved. It is hoped that the adjustable welding jigs can support and promote the assembly and welding activities of the copper tube in the refrigeration and air conditioning and have been used as a learning tool by lecturers and students. Additionally, this adjustable welding jig can further enhance the efficiency and quality of the user's work. Notwithstanding, the development of the adjustable welding jigs using the ASIE model application in the refrigeration and air conditioning workshop also ensures the user's safety while performing welding work in the workshop because the product features are ergonomic, well designed, versatile, adaptable and able to comply with precision requirements of the welder.

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