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Safety education management in welding robotic laboratory

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Safety education management in welding robotic laboratory

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Abstract. The purpose of this study is to develop the OSH education management system for the laboratory of the welding robot arm. This study employed Research & Development (R & D) with the ADDIE model. The research consisted of two industries that have used welding robotic arms and the vocational schools of technology, which have welding workshops. The feasibility of the research results was done through audit-trail triangulation from relevant experts, i.e educators, competency test assessors, operators and/or experts from the industry. The results were in the form of the OSH for educational management system and the redesign draft of vocational education laboratory model on welding techniques using robotic arms to accommodate OSH, 5S - *Seiri* (Sort), *Seiton* (Set in order), *Seiso* (Shine), *Seiketsu* (Standardize) and *Shitsuke* (Sustain) and the ergonomics of the room. The results of the needs analysis related to the welding robot arm of the industrial arm are used as the basic pattern to redesign, develop and to compile the implementation of the welding education laboratory model assisted by robotic arms and complete with the OSH education management system.

1. Introduction
The layout of the vocational education laboratory must be able to expedite the learning process of practice to be faster, more accurate, and more relevant. Besides, it can also guarantee safety and health, as well as its comfort to support the efficiency and effectiveness of the learning process.

The problem is the way to analyze and redesign the vocational education laboratory in the welding automation process that is comfortable, healthy, and safe with robotic arms to increase learning productivity. The design of the vocational education laboratory includes dimensions, size, coverage range, the layout of tables and chairs, machines or other supporting tools that are associated with user limitations.

1.1. Laboratory layout
The layout of the vocational education laboratory for welding should accommodate the space for robots and other supporting equipment to support the learning process. Workplaces in vocational education laboratories are a well-designed room for machines or tables and other supporting equipment that can fortify learning productivity [1].

Redesigning the learning layout that accommodates anthropometric limitations is aiming to enable students to carry out their learning activities that are comfortable, healthy and safe in order to avoid illness due to its practical work, for example, cumulative trauma disorders (CTDs). By doing so, it is expected that the learning process can run effective and efficient.

Good interaction between the welding robot and its users is based on anthropometric data and the limitations of the student movement (human-factor). The awkward or extreme movements need a lot of repetition and excessive energy so it should be reduced by setting the layout of a robotic welding arm and other supporting equipment as well as other raw materials. Anthropometry is used as ergonomic consideration in redesigning including measurement of certain dimensions and characteristics, such as shape, size, height, width, the weight of the human that covers the body, volume, center of gravity, device of inertia and mass of body parts [8].

1.2. Welding robot arm

Automation as mechanization in the work process to make sure its comfort, cost savings, and outcome improvement [3] [6]. In this automation era, robots are used as all automatic instruments in the form of programmable multi-function manipulators that replaces some human functions to perform dangerous tasks. For welding case, the use of a robotic arm in the manufacturing industry will be more efficient and effective. Robots are generally employed to perform unsafe and dangerous tasks, as well as repetitive and unpleasant work [4]. Robots can perform material carrying, handling, assembling, welding, loading and unloading, painting and spraying. Robots are very useful because they have high precision, intelligence and endless energy in doing tasks instead of humans. The robot industry is a multifunctional design that can be re-programmed to move material, parts, tools or special devices through the movement of programmed variables for the various tasks [2]. Usually, the robot welding system consists of robots, welding equipment, controllers, working clamping devices and motion devices to take workpieces right in their position. It also contains robotic motion equipment to move around the robot and good welding orientation, sensors, and safety equipment [5]. The welding process itself is a fabrication process that combines materials, such as metals or thermoplastics by causing coalescence.

The use of robots aims to support comfort, safety, security, and health, and to overcome human limitations. The existence of automation will greatly affect the way of human and machine interactions in redesigning the welding learning system with ergonomic robot arms [6]. The implementation of the robot arm for the welding process that function in the spot welding process, arc welding and friction stir welding [7]. With the increasing application of welding robot technology, it can reduce the operator involvement and automatic control of welding parameters, robot movement tracks, error detection, and incorrect changes [5].

1.3. Zerosicks

Zerosicks is an analytical method for managing the work processes in a certain work unit. This method is usually used in industry or other institutions to provide solutions based on the accident analysis. The zerosicks description contains components related to OSH from hazard to standardization. ZEROSICKS stands for several terms that are often used in OSH, namely Hazard, Environment, Risk, Observation, Opportunity, Occupational, Solution, Implementation, Culture, Climate, Control, Knowledge, Knowhow, and Standardization. The management system of zerosicks OSH is a continuation of the hazard exploration, risk observation, solution identification, OHS adjustment through strengthening the climate and standard knowledge based on the accident events.

Zerosick analysis consists of several aspects including; (1) Hazard, which is related to potential sources of danger. Hazard or potential sources of danger consisting of physical hazards, biological hazards, chemical hazards, psychological hazards, ergonomic hazards, environmental hazards, and mechanical hazards, (2) Environmental, related to working environment conditions, (3) Risk, namely combinations and the consequences of a dangerous event and the chance of such an occurrence. Risk analysis can also be a danger that can occur due to an action or process carried out by a person. (4) Observation is related to the factors that cause danger. (5) Opportunity is the possibility of losses incurred in an event cause danger, (6) Occupational is the cause of the occurrence of hazards that exist in the workspace, (7) the solution is an effort to reduce and eliminate the risks that exist in the work environment. The Solution is also related to how to solve problems to prevent work accidents, here Personal Protective Equipment (PPE) which consists of head and body protection is one of the right solutions in preventing accidents at work. The application of 5R/ 5S is also a solution right in structuring the work environment to prevent accidents and illnesses due to work [9]. (8) Implementation is in the form of implementation carried out in a work scope to support the creation of OSH, Culture, Control, Climate, namely getting used to the Occupational Safety and Health (OSH) behavior, then for further control to always be maintained to create an atmosphere/ climate that is safe and healthy at work, (9) Knowledge is knowing facts and information about the problems faced. Knowhow is knowledge to do something or the ability to take action on problems faced based on the knowledge that is owned, (10) Standardization is a reference to an activity based on regulations.

2. Research Method

This R & D research is limited to the trial stage of the design draft feasibility of. The research subjects were two medium industries that had begun to implement robotic technology in the process of welding for their manufacturing products. Mix-mode analysis through in-depth observation in the industrial workplace of a welding robot arm by having data collection with a qualitative approach, i.e. observation, interview and content analysis on documented data. This stage was equipped with direct measurements on the dimensions of the learning place, supporting tools, user's anthropometry, and zerosicks analysis.

The results of the case study analysis were in the form of sketch drawings, construction, and activity systems related to the users. The trial results theoretically were based on audit-trail triangulation from the relevant experts by using ECCS approaches (eliminate, combine, change, simplify) and QFD (quality function deployment). The indicators involved ease of application (applicative, adaptability and flexibility), advantages (strength), shortcomings (weakness), opportunities for re-improvement and obstacles that may arise during the application (threat). The descriptors are more comfortable, healthy and safe by accommodating human factors.

This design includes the new layout for vocational education laboratories in the process of welding practices using robotic arms. Data flow diagrams and flowcharts were used to describe the sequence of learning processes based on motion and time analysis and to determine critical control points that need to emphasize the aspects of OSH, 5S, and ergonomics.

3. Discussion on Redesign Result

The welding robots generally had the dimensions of $400 \times 220 \times 780$ mm^3, with 6 degrees of freedom (DOF), the weight of 25.7 kg and the working radius of 794 mm. The basic mechanism of the robot can be the cartesian, cylindrical, spherical and anthropomorphic coordinate system. It can be shown in figure 1. The coordinate system of the basic mechanism of the welding robot will determine the configuration and dimensions of the robot's workspace that allows controlling movement of the robot body. From these data, it can be identified the width of the welding robot's workspace based on the anthropomorphic form with the approximate working area of 800 mm.

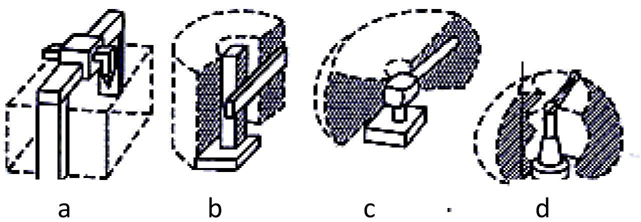

Figure 1. Robot working area with the coordinate system; (a) cartesian, (b) cylindrical, (c) spherical and, (d) anthropomorphic [10].

Based on the observation data, the room was divided into study rooms and welding practices arranged in U / L configurations to accommodate free movement of the students. This room was equipped with provocative and preventive posters, such as standardized learning operations, OSH information, emergency evacuation procedures, 5S and product quality.

The area of welding learning should be 12×5m where each robot was separated by a safety fence with translucent material. It will automatically close when the welding process was undergone. It also equipped with air channel to expel gas and dust hazards. The design of area are shown in figure 2.

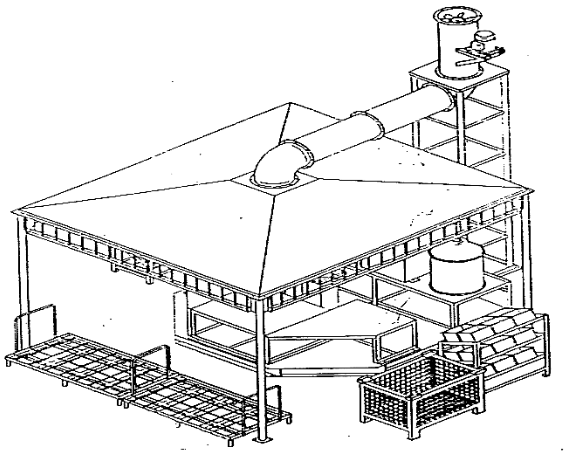

Figure 2. The laboratory for vocational schools

The dimensions for each robot room based on the robot maintenance and inspection guide were 3.296 (width) m × 3.945 (length) m × 3.0 (height) m. The height of the air canal was 4.620 m. In the spaces for one another were given a distance of 0.5m and the distance of the robot wall was about 1m to make the students more freely. The operation of the welding robot arm through Teach pendant was located with 1,025mm above the floor surface suited with the student anthropometry when standing. The learning dimension ranged from 304.6 to 426.7 cm. Laboratory layout based on the above requirements can be seen in Figure 3.

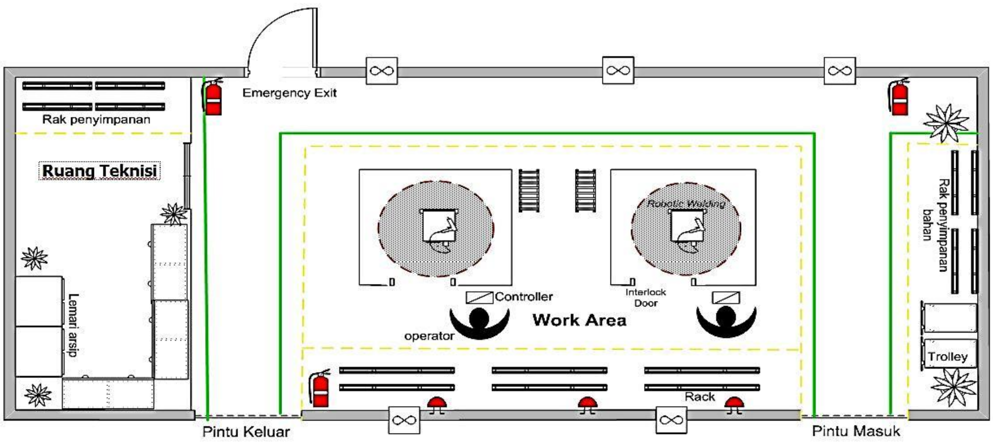

Figure 3. Laboratory layout

The ease of the application in case of adaptability and flexibility is relatively good because the needs of supporting resources for information, technology, equipment, raw materials, and related experts have been available. Those can be easily found in the market of Indonesian. The information about guidelines and design requirements is also easy to obtain. The difference in storage height from the surface was arranged to facilitate the product transfer by utilizing gravity. The design layout of the vocational education laboratory has fulfilled the ergonomic aspects so that the comfort, health, and safety of learning will be fulfilled as well.

The descriptors are more fun, comfortable, healthy and safer because the student's space is more flexible and consider the ergonomic aspects to minimize the risk of robotic arms clash. All machines, raw materials, and supporting equipment are arranged neatly based on the priority needs so that they are easily accessible (5S). It is also completed with natural lighting through glass roofs and right temperature which is regulated by split air conditioners, and remote operation for the machines and other equipment. The health and safety aspect can be achieved because the source of potential hazards can be isolated, eliminated and protected by the safety fence, and an exhaust fan for smoke and dust removal. The availability of complete personal protective equipment is also to guarantee adequate learning safety. This safe and comfortable condition can increase the productivity of practice learning. Those can be realized through the atmosphere, the color of the wall, the cleanliness, the tidiness, and the layout of the lab room.

The safety awareness related to the use of a welding robot arm by operators is a crucial predictor that must be considered. As an example is the alarm sound for the failure sign or the completion in the practice learning process. This is also related to the student's ability to understand the interaction of the machine and equipment in case of the room layout adapted to the characteristics of the user's anthropometric (human factor). The way of users perceive environmental elements related to practical learning processes, duration, size, shape, weight, color, ease of access and operation, interpretation, or projection of the device's status (e.g. teach pendant or human-robot interface) for students. The impact is the improvement of the students' learning performance as the users.

Zerosicks analysis related to PPE in the practical learning of the welding robot laboratory are safety helmet to prevent collision in the head, safety glass to protect the eyes from the danger of dust exposure, earplugs to protect from engine noise hazards, face shields to protect various risks of facial injuries from workplace accidents, and safety masks to protect against the dangers of poor air quality. As the body protector from mechanical hazards, the students are also required to use a wearpack. Besides, safety shoes and gloves are very important to protect limbs from work accidents. The physical danger in the form of heat, odor, sparks should also be avoided during the student practice process. The chemical hazards that may be generated in the welding process are corrosive materials, metal residual welding processes, and toxic fumes. The psychological hazards do not only affect the operator but also the people around the welding robot in the form of stress and boredom. The ergonomics hazards are related to body anthropometer or body size, and the relationship between work tools and operators that are a bad layout, wrong work system, improper machine design and wrong body position that create a potential cause of accidents in the practice process. The 5S analysis consisting of the sort, set in order, shine, standardize and sustain are implemented by the process of checking, categorizing items, labeling and preparing for the store, dispose and destroy used items. The set in order process is done by storing materials or equipment in accordance with the place to speed up the time to obtain materials or equipment. The shine process is realized in the form of cleaning the workplace, environment, machine, equipment, and goods so that there is no dust and dirt. The standardize principle is done to maintain the results achieved in the previous 3S by standardization. This process is manifested in the determination of standards of cleanliness, placement, structuring and communicating to each practitioner who is carrying out practices in the laboratory. The sustain principle is carried out by enhancing the students' personal habits to maintain and improve what has been achieved.

The assessment from the expert media showed the mean score of 3.08, the standard deviation of 0.282 with the percentage of 77.08% respectively. Meanwhile, the OSH material expert assessment gave the mean score of 3.40, the standard deviation of 0.498 with a percentage of 85% respectively. Overall, the validity level of the vocational education laboratory design in the welding robotic arm according to the user can be categorized as "Good" with the percentage of 78.175%.

4. Conclusion

Based on the description above, it is clear there are many factors that support productivity and learning performance. One of the factors is the layout of the laboratory. The aspects of comfort, health, and safety of learning have been revealed in order to improve learning productivity. The design of the vocational education laboratory on this study includes dimensions, size, coverage range and layout of tables, chairs, machines and other supporting equipment that is adjusted with human limitations (human-factor).

The results of this design can also be used in real conditions by the industry as training material on occupational health and safety (OSH). The design result of the vocational education laboratory is one of the proposed improvements related to the condition of the conventional vocational education laboratory, especially in the welding course. The use of the robotic arm is expected to make the students who practice as operators can feel comfortable, happy, and enjoyable in order to enhance the learning motivation.

The comfortable, healthy and safe laboratory is also related to the use of tools that have been adapted to the user's anthropometry, and pay attention to kaizen management rules, so the redesigning process of learning equipment needs to be done by referring to 5S principles (sort, set in order, shine, standardize and sustain).

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