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## Effectiveness of An Active Learning Intervention on Enhancing the Knowledge and Attitude for Mitigating Health Risks among Electronic Waste Dismantling Workers: A Study in Buriram Province, Thailand

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### Abstract

*E-waste dismantling workers are exposed to various occupational hazards, including inhalation and dermal contact with hazardous substances and musculoskeletal injuries due to improper work postures. Educational interventions are essential in mitigating these risks by improving knowledge and promoting positive attitudes toward safety practices. This study employed a one-group pretest–posttest design to evaluate the effectiveness of an active learning intervention among e-waste dismantling workers in Daeng Yai Sub-district, Ban Mai Chaiyaphot District, and Ban Pao Sub-district, Phuthaisong District, Buriram Province, Thailand. A total of 99 workers participated in a structured training program covering health risk prevention practices. Data was collected using pre- and post-education questionnaires and analyzed using a paired sample t-test at 0.01 and 0.001 for the knowledge and attitude tests, respectively. The findings revealed significant improvements in both knowledge and attitudes among participants. The mean knowledge score increased from 5.32 to 7.34 ( $p < 0.001$ ), while the mean attitude score improved from 30.02 to 31.59 ( $p = 0.002$ ). These results suggest that educational interventions can effectively enhance knowledge and develop positive attitudes toward health risk mitigation. Targeted educational interventions play a crucial role in improving knowledge and attitudes regarding occupational health risks among e-waste dismantling workers. Future research should evaluate the long-term impact of this intervention on safety practices and behavioral changes.*

**Keywords:** *Electronic Waste Worker, Occupational Health, Educational Intervention, Active Learning, Knowledge and Attitude Improvement.*

### Introduction

The rapid growth of information technology and increased consumerism have led to a significant increase in electronic waste (e-waste), also known as end-of-life electrical appliances and items (Dutta et al., 2023). It was estimated that roughly 54 million tons of e-waste were produced annually, with that amount expected to rise to 75 million tons annually by 2030 (Al-Salem et al.,

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2022). The global e-waste production is estimated to be around 54 million tons annually, with an expected rise to 75 million tons by 2030. Asia generates the most e-waste, followed by America, Europe, Africa, and Oceania (Kumar et al., 2024). Recycling e-waste is becoming increasingly challenging due to illegal commerce and informal recycling, with low-income communities disposing of e-waste improperly and without scientific methods (Liu et al., 2023). Around 80% of e-waste from developed countries is illegally transported to developing countries, including China, Nigeria, Pakistan, India, and Ghana (Sthiannopkao & Wong, 2013). Improper recycling practices in developing countries lead to the production of hazardous substances such as polychlorinated biphenyls (PCBs), polychlorinated diphenyl ethers (PCDEs), heavy metals, and toxic gases include dioxin and furan (polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs)) (Dutta et al., 2023). These substances pose severe health risks to humans through inhalation, dietary intake, soil or dust ingestion, and skin contact with e-waste materials (Song & Li, 2015). A systematic review has found that exposure to hazardous substances from e-waste can lead to alterations in thyroid function, changes in cellular expression and function, negative outcomes for newborns, variations in temperament and behavior, and impaired lung function (Liu et al., 2023).

In Thailand, the Pollution Control Department (PCD) reported a significant increase in e-waste from 359,070 tons in 2012 to 439,495 tons by 2022. The annual growth rate of e-waste has been around 2% (PCD, 2017). Unfortunately, only 10% of e-waste is managed properly by local governments, second-hand shops, and manufacturers/distributors. The remaining 90% is improperly managed by traveling trucks/second-hand shops, who improperly collect and dismantle the waste, sell it as valuable materials to recycling factories, and dispose of it by burning it outdoors or dumping it in municipal waste disposal sites and vacant areas (PCD, 2022). Over 100 informal e-waste dismantling sites are located across 17 provinces, such as Kalasin, Buriram, and Samut Prakan, where individuals disassemble electrical appliances and collect recyclable components (PCD, 2021).

Several districts in Kalasin and Buriram Provinces are known as major e-waste recycling spots, valuable components often recovered using primitive methods (Bungadaeng et al., 2019). In Buriram Province, the growing evidences from several studies has identified contamination of hazardous substances from e-waste in environments, including soil, air, surface water, and groundwater (Amphalop et al., 2020; Kongsricharoen et al., 2020; Thongkaow et al., 2022a). Human exposure to hazardous substances resulting from e-waste has also been found. A study in Daeng Yai Sub-district found the median blood lead level among 132 children under five was 3 µg/dL, with 14.4% having blood lead levels exceeding the Centers for Disease Control and Prevention (CDC) standard (Srisaeng & Inmuong, 2013). Another study also found that lead and cadmium in the blood of e-waste workers in Daeng Yai Sub-district were  $5.63 \pm 2.86$  and  $3.92 \pm 1.13$  µg/dL, respectively. While blood lead and cadmium levels were  $0.97 \pm 0.43$  and  $1.12 \pm 0.43$  µg/dL, respectively, in Ban Pao Sub-district (Sirichai, 2019). Moreover, Bungadaeng (2018) indicated that the 95% confidence interval for the lifetime cancer risks faced by e-waste workers in Daeng Yai exposed to PM<sub>2.5</sub> and PM<sub>2.5-10</sub> bound PAHs through inhalation and skin contact after burning were between  $1.74 \times 10^{-4}$  and  $3.74 \times 10^{-4}$ , resulting in a 100% unacceptable risk. These findings emphasize the health risks faced by individuals living in e-waste dismantling areas, highlighting the urgent need for interventions to minimize exposure to hazardous substances.

Given these realities, the need for comprehensive educational programs on health risks and proper protective measures has become paramount. Previous interventions have demonstrated

that educational intervention significantly enhanced the knowledge and attitudes toward health risks and the importance of protective equipment (Chanthahong et al., 2020; Otu et al., 2016). Therefore, we conducted an active learning intervention for e-waste dismantling workers at e-waste dismantling sites in Buriram Province in order to enhance their knowledge and attitudes regarding the hazards they confront. The aim of this study was to evaluate the effectiveness of the intervention program.

## Materials and Methods

### *Study design and setting*

A quasi-experimental study using a one-group pretest–posttest design was conducted to evaluate the effectiveness of active learning interventions on enhancing the knowledge and attitude of informal e-waste dismantling workers. The workers were evaluated using a pre-test questionnaire before an active learning intervention. Following that, the post-test questionnaire was administered. This study was conducted in well-known e-waste dismantling sites in the two rural communities located in northeastern Thailand, including Daeng Yai Sub-district, Ban Mai Chaiyaphot District (15°35'17.6"N 102°53'20.7"E), and Ban Pao Sub-district, Phutthaisong District (15°37'33.26"N 102°53'40.52"E) (Figure 1). These informal dismantling sites have been operating for more than a decade. Approximately 30 e-waste dismantling households and 316 informal separators were observed in 2017 (Thongkaow et al., 2022b).

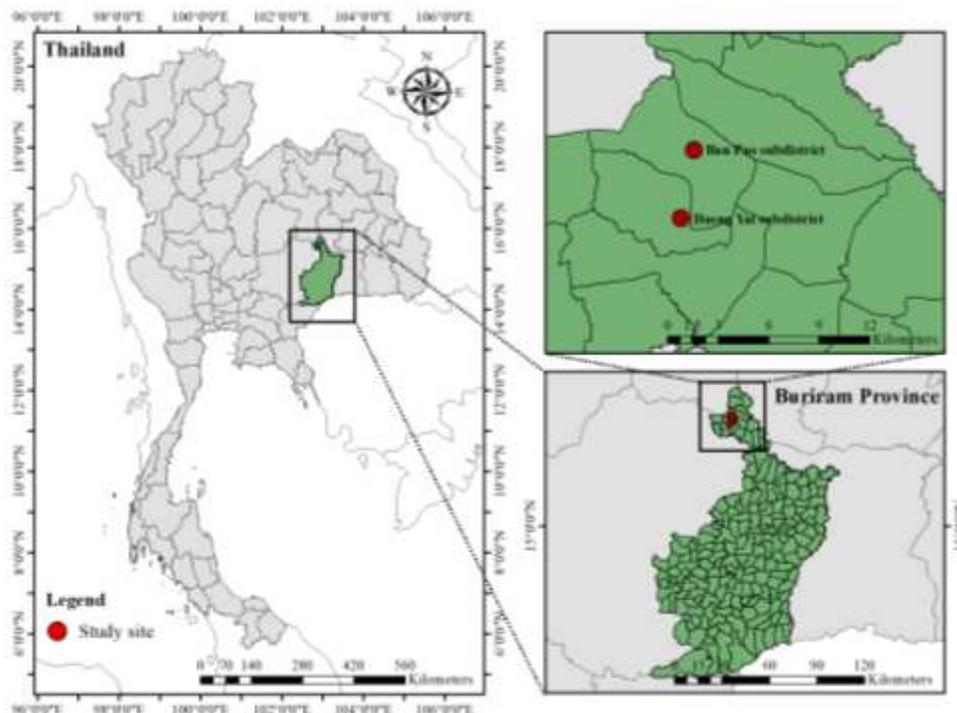


Figure 1 E-Waste Dismantling Sites in Buriram Province, Thailand

### Participant Recruitment

We involved a purposive sampling technique to recruit informal e-waste dismantling workers in two e-waste dismantling communities at two Subdistrict Health Promotion Hospitals (SHPH) in

these districts. The sample size was determined using Cohen's statistical power analysis (Cohen, 1977), with an effect size of 0.30 (medium), a significance level ( $\alpha$ ) of 0.05, and a statistical power ( $1-\beta$ ) of 0.08. A sample size of 94 was desired with a 10% attrition rate to account for anticipated dropouts. Workers who were actively engaged in e-waste dismantling operations were included. Whereas workers who did not complete the entire educational program and the pre- and post-test questionnaires were excluded from the final analysis. The final number of participants was 99 participants.

### Active Learning Intervention

We proposed active learning methods for the training program. The training programs were delivered over a two-week period, with each session lasting approximately two hours. The format included lectures, instructional materials, hands-on activities, and group discussions, as detailed in Table 1. Through logical arguments, we provided information on good and bad facts, encouraging participants to make informed decisions. The program was established to implement three major topic sessions for the workers, including:

- 1) **Inhalation Hazards:** Instruction on the risks of dust and toxic fumes (e.g., heavy metals and polycyclic aromatic hydrocarbons) in their working environment and the use of face masks. The workers were trained in the proper use of face masks (N95, activated carbon filter masks) to prevent inhalation exposure.
- 2) **Contact Hazards:** Training on hand hygiene and glove use, with an emphasis on how different types of gloves protect against specific chemicals. Hands-on demonstrations included testing handwashing efficacy under UV light.
- 3) **Postural Hazards:** Instruction on the importance of correct sitting and lifting postures to prevent musculoskeletal injuries, using spinal models to demonstrate the effects of poor posture.

| Topic   | Objectives   | Training methods  | Training tools   |
|---|--|---|--|
| Exposure through inhalation and its prevention            | <ol style="list-style-type: none"> <li>1. To give knowledge on the advantages and disadvantages of face masks and their applications</li> <li>2. To promote good attitudes to wearing a face mask and to raise awareness of the consequences of not wearing one</li> </ol> | <ol style="list-style-type: none"> <li>1. Education on the risks of dust and toxic fumes</li> <li>2. Explanation of the advantages and disadvantages of face masks, how to wear them, and their key uses</li> <li>3. Trainees perform tests while wearing face masks, where they try to smell fragrance to assess the mask quality</li> </ol> | <ol style="list-style-type: none"> <li>1. Educational poster</li> <li>2. Cloth masks</li> <li>3. Face masks</li> <li>4. Activated carbon filter masks</li> <li>5. Half-face chemical protective masks</li> <li>6. Half-face chemical respirators with activated carbon filter</li> </ol> |
| Exposure to toxic substances through contact and possible | <ol style="list-style-type: none"> <li>1. To give knowledge on the advantages and disadvantages of gloves and their applications</li> </ol>  | <ol style="list-style-type: none"> <li>1. Education on the risks of exposure to toxic substances through contact</li> <li>2. Explanation of the advantages and</li> </ol>   | <ol style="list-style-type: none"> <li>1. Educational poster</li> <li>2. Rubber gloves for examination</li> </ol>  |

| Topic                           | Objectives  | Training methods   | Training tools  |
|---------------------------------|---|--|---|
| protection measures             | 2. To promote good attitudes to wearing gloves and to raise awareness of the consequences of not wearing them   | disadvantages of gloves and their key uses<br>3. Explanation of 7-step hand washing<br>4. Efficiency tests on hand washing by applying a fluorescent cream on hands and dividing the trainees into 3 groups: no hand washing, normal hand washing, and 7-step hand washing. Finally, testing the hands under a UV lamp to assess if there was any cream remaining not washed off | 3. Acid-resistant gloves<br>4. Cut-resistant gloves<br>5. Chemical-resistant gloves<br>6. Cotton gloves<br>7. Hand-washing performance test kit |
| Injuries from bad work postures | 1. To give knowledge on how to sit properly and to raise awareness of the consequences of improper sitting<br>2. To promote good attitudes to a proper sitting position | 1. Education on injuries from bad work postures<br>2. Explanation of proper sitting positions and the consequences of improper sitting<br>3. Demonstration of proper sitting using a spinal model and herniated disc characteristic model  | 1. Educational poster<br>2. Spinal model<br>3. Herniated disc characteristic model  |

Table 1. Training Program Structure for Knowledge and Attitude Development of Worker

### Pre- and Post-test Questionnaire

Before and after the training, participants were requested to complete pre- and post-test questionnaires. Most respondents were older and had poor educational levels with limited reading skills; therefore, data was collected through face-to-face interviews, and the questionnaire contained only 24 items. The pre- and post-test questionnaire was designed to evaluate their knowledge and attitudes toward mitigating health risks associated with working at an e-waste dismantling site, which consists of three parts, including 1) demographic information (sex, age, education level), 2) knowledge assessment, and 3) attitudes assessment. The knowledge assessment part consists of 12 items with true-or-false questions. And the attitude assessment part consists of 12 questions using a 4-point rating scale: strongly agree, agree, disagree, and strongly disagree. All the questions were reviewed by 3 experts and had an Index of Item-Objective Congruence (IOC) of greater than 0.5, which indicated strong content validity (Turner & Carlson, 2003). The details of the questionnaire items are presented in Table 2.

| Section   | Question  | Full score | Grading   |
|-----------|---|------------|---|
| Knowledge | 1. Features of personal protective equipment (PPE)<br>2. Consequences of improper work postures | 10         | 0–3 points: low level<br>4–7 points: moderate level<br>8–10 points: good level      |
| Attitudes | 1. Prevention of exposure to hazards<br>2. Health risks from exposure to hazards                | 48         | 12–24 points: low level<br>25–36 points: moderate level<br>37–48 points: good level |

Table 2. The Questionnaire Components and Scoring Criteria

### Ethical Consideration

The research project was approved by the target group and endorsed by the Research Ethics Review Committee for Research Involving Human Research Participants, Health Sciences Group, Chulalongkorn University, Certificate number: 230/2016. Participants were recruited using verbal informed consent. We fully stated the objective of the study and the approaches involved. Participants were informed that they might decline or withdraw from the study at any moment without giving a reason. Refusing to participate or withdrawing would have no effect on their eligibility for medical care or other benefits.

### Statistical Analysis

We used SPSS Statistics 17.0 to analyze all of the data in this study. Descriptive statistics was used to analyze the frequency, percentage, mean, and standard deviation (SD) of variables. For inferential statistics, a paired sample t-test was employed to compare the pre- and post-test scores on knowledge and attitudes of respondents, with the level of significance set at 0.01 and 0.001 for the knowledge and attitude tests, respectively.

### Results

#### Demographic Information

Among 99 workers involved in this study, the majority of respondents were female, with a mean age of 56.5%, while the proportion of males was 43.4%. The average age of the participants was  $48.4 \pm 9.5$  years. Up to 78.8% of respondents had graduated from elementary school, followed by junior high (20.2%), with only 1.01% having graduated from senior high. The frequency distribution of demographic information of participants is shown in Table 3.

| Variables (N = 99) | Frequency (n) | Percentage (%) |
|--------------------|---------------|----------------|
| <i>Sex</i>         |               |                |
| Male               | 43            | 43.4           |
| Female             | 56            | 56.6           |
| <i>Age (years)</i> |               |                |
| < 40               | 17            | 17.17          |
| 40–49              | 37            | 37.37          |
| 50–59              | 33            | 33.33          |

| Variables (N = 99)     | Frequency (n) | Percentage (%) |
|------------------------|---------------|----------------|
| ≥ 60                   | 12            | 12.12          |
| Overall (mean ± SD)    | 48.4 ± 9.5    |                |
| <i>Education level</i> |               |                |
| Elementary school      | 78            | 78.8           |
| Junior high school     | 20            | 20.2           |
| Senior high school     | 1             | 1.01           |

Table 3. The Frequency Distribution of Demographic Information of Participants

### Knowledge Levels Toward E-Waste Risk Prevention

Table 4 presents the average pre- and post-training scores for knowledge about risk prevention from e-waste hazards of respondents. Before the training, the worker had a modest level of knowledge of  $5.32 \pm 1.63$ . Considering each item score, respondents had high pre-training scores (items 9-11) for work postures, with 71.72 to 88.89% of respondents responding with correct answers. Meanwhile, they received low scores for proper mask and glove usage (items 1-7), ranging from 0.07 to 0.28, as well as the lowest proportion of correct answers (7.07 - 29.29% of respondents). Item 8 got a high score of  $0.96 \pm 0.19$ , and 96.97% of respondents answered correctly. After the training, the overall average score was obviously increased to be at a good level, with an average of  $7.55 \pm 1.59$ . In addition, the number of respondents responding correctly to all questions increased. Unfortunately, the score and proportion of correct responses regarding the proper use of gloves (items 1, 3, and 4) remained low. The number of participants with correct answers to all items is presented in Table S1.

| No. | Question   | Pre-training score |      | Post-training score |      |
|-----|--|--------------------|------|---------------------|------|
|     |  | Average            | SD   | Average             | SD   |
| 1.  | Latex gloves can protect against weak acids                                      | 0.10               | 0.30 | 0.37                | 0.48 |
| 2.  | Latex gloves can protect against all kinds of chemicals                          | 0.24               | 0.43 | 0.75                | 0.43 |
| 3.  | Nitro gloves can't protect against thinners                                      | 0.28               | 0.45 | 0.35                | 0.48 |
| 4.  | Chemical-resistant gloves can protect against all kinds of chemicals             | 0.20               | 0.40 | 0.28                | 0.45 |
| 5.  | Cloth masks can protect against dust and chemicals                               | 0.21               | 0.41 | 0.69                | 0.46 |
| 6.  | N95 masks can protect against dust and chemicals                                 | 0.07               | 0.25 | 0.51                | 0.50 |
| 7.  | Masks with an activated carbon filter can protect against all types of chemicals | 0.17               | 0.37 | 0.28                | 0.45 |
| 8.  | Masks with an activated carbon filter can also protect against dust              | 0.96               | 0.19 | 1.00                | 0.00 |
| 9.  | Sitting and working can affect the lumbar spine                                  | 0.94               | 0.22 | 0.99                | 0.10 |
| 10. | Sitting and working can affect the spine in the neck                             | 0.88               | 0.31 | 0.95                | 0.22 |

| No.                           | Question   | Pre-training score |      | Post-training score |      |
|-------------------------------|--|--------------------|------|---------------------|------|
|                               |  | Average            | SD   | Average             | SD   |
| 11.                           | Pain from working is usually associated with older persons | 0.71               | 0.45 | 0.76                | 0.43 |
| 12.                           | Sleep does not affect the spine                            | 0.52               | 0.50 | 0.59                | 0.49 |
| The overall average of scores |  | 5.32               | 1.62 | 7.55                | 1.59 |
|                               |  | Moderate           |      | Good                |      |

Table 4. Pre-And Post-Training Scores for Each Knowledge Item

### Attitude Levels Toward E-Waste Risk Prevention

The results presented in Table 5 revealed that the average pre-training scores for attitude regarding risk prevention from the e-waste hazards of the respondents was moderate level, with an average of  $30.02 \pm 3.84$ . Considering each attitude item, Item 1 had the lowest score ( $1.91 \pm 0.75$ ), with only 16.16 respondents providing adequate attitude answers (Table S2). In contrast, they scored high on items 2 and 8, averaging 3.39 and 3.29, respectively. Up to 89.90 percent of respondents provide adequate attitude answers to these questions. After the training, the post-training scores of the respondents were slightly increased to  $31.59 \pm 3.91$ . As a result, only slight differences between pre- and post-training ratings were observed in this study.

| No.                   | Question   | Pre-training score |      | Post-training score |      |
|-----------------------|--|--------------------|------|---------------------|------|
|                       |  | Average            | SD   | Average             | SD   |
| 1.                    | Hand washing after work effectively prevents disease                                       | 1.91               | 0.75 | 2.26                | 0.97 |
| 2.                    | Chemicals frequently enter the body through pathways other than the hands                  | 3.39               | 0.72 | 3.23                | 0.68 |
| 3.                    | Long periods of hand washing with soap are a waste of time                                 | 2.69               | 0.90 | 3.04                | 0.84 |
| 4.                    | Most illnesses are caused by inhaling germs.   | 2.01               | 0.78 | 2.12                | 0.82 |
| 5.                    | Wearing a face mask is hot and uncomfortable for working                                   | 2.43               | 0.92 | 2.68                | 0.87 |
| 6.                    | Waste dismantling jobs are unlikely to expose workers to chemicals through breathing       | 2.48               | 0.90 | 2.67                | 0.91 |
| 7.                    | Face masks are costly to purchase  | 2.78               | 0.97 | 2.92                | 0.70 |
| 8.                    | Wearing a face mask while working can help prevent illness                                 | 3.29               | 0.67 | 3.18                | 0.69 |
| 9.                    | I tend to prioritize ease of work over proper posture.                                     | 2.09               | 0.72 | 2.10                | 0.69 |
| 10.                   | When I have back pain, I believe regular massages can help                                 | 2.26               | 0.85 | 2.30                | 0.88 |
| 11.                   | Sitting on the floor and working can result in paralysis                                   | 2.51               | 0.87 | 2.91                | 0.76 |
| 12.                   | Simply avoiding lifting heavy objects can help reduce the risk of suffering from back pain | 2.14               | 0.75 | 2.14                | 0.83 |
| The sum of all scores |  | 30.02              | 3.84 | 31.59               | 3.91 |

| No. | Question | Pre-training score |    | Post-training score |    |
|-----|----------|--------------------|----|---------------------|----|
|     |          | Average            | SD | Average             | SD |
|     |          | Moderate           |    | Moderate            |    |

Table 5. Pre-And Post-Training Scores for Each Attitude Item

Note: Adequate attitude was defined as responding Strongly Agree or Agree to positively worded items and Disagree or Strongly Disagree to negatively worded items. The counts reflect the number of respondents meeting these criteria

### The Efficacy of Intervention on the Knowledge and Attitude Development

Table 6 shows the results of statistical analysis, which found that the training could significantly increase the knowledge level of workers in preventing hazards and the health risks from e-waste dismantling activities ( $p < 0.001$ ), with the mean score increasing from 5.32 to 7.55. Meanwhile, the training also demonstrated a significant improvement in good attitudes ( $p = 0.002$ ), even though there was a slightly different attitude score (from 30.02 to 31.59).

| Assessment   | N  | Score   |      | t      | p-value |
|--|----|---------|------|--------|---------|
|  |    | Average | SD   |        |         |
| <b>Knowledge</b>   |    |         |      |        |         |
| Pre-training   | 99 | 5.32    | 1.62 | -9.960 | <0.001* |
| Post-training  | 99 | 7.54    | 1.59 |        |         |
| <b>Attitudes</b>   |    |         |      |        |         |
| Pre-training   | 99 | 30.02   | 3.84 | -3.156 | 0.002** |
| Post-training  | 99 | 31.59   | 3.91 |        |         |
| Remark: * a significant level of 0.001, ** a significant level of 0.01 |    |         |      |        |         |

Table 6. Paired Sample T-Test Results on Pre- and Post-Training Knowledge and Attitudes

## Discussion

In this study, a majority of the workers were in primary school. Educational level was found to influence the knowledge, attitude, and practices (KAP) of the population in e-waste recycling areas (Adanu et al., 2020; Hamzah et al., 2020). Thus, the training was designed with active learning, which is recognized as an essential teaching strategy that "changes the type and level of learning, which includes demonstrably enhanced recall" (Lasater et al., 2009). Our training was created by presenting active learning approaches, which include lectures, instructional materials, hands-on activities, and group discussions. The instructional materials used in this study were crucial as they emphasize the importance of participant participation in activities and the outcomes of their efforts to prevent work-related hazards, which piques the interest of workers and enhances their comprehension of the material. As suggested by Campbell (1999), instructional materials improve the teaching and learning process by providing the knowledge and skills.

Considering the knowledge and attitude score of workers before training, we observed that the worker had a modest level of knowledge ( $5.32 \pm 1.63$ ). This suggested that the personnel had just primitive knowledge of risk prevention. In this study, the workers scored high on work postures, indicating that they had an adequate understanding of the risk of sitting and working

with the improper posture, which is consistent with Henderson et al. (2018); nevertheless, they might not completely understand the long-term health risks. In contrast, the worker demonstrated a clearly low level of knowledge about the function of different types of masks. This is to be expected, given a study in Addis Ababa, Ethiopia, which also found that two-thirds of health workers were unable to identify the difference between surgical masks, N95 masks, and face masks (Demissie Gizaw et al., 2015). They also had a relatively low knowledge score for proper glove usage; nevertheless, even after training, their knowledge score remained low. This is because of confusion in the specific features and protective capabilities of different glove types. They are generally aware of why gloves should be worn, but they wear them mostly to avoid hand injuries rather than to protect themselves against exposure to hazardous substances. Similar to Darda'u Rafindadi et al. (2022), who found that although almost all respondents understand the purpose of protective gloves, only 76% were aware of the different kinds that are used. This can be suggested that workers who handle e-waste typically have low awareness of the health and environmental risks associated with their occupations (Kumar & Gupta, 2021), which makes it difficult for them to select the appropriate PPE. In part of the attitude level, before the training, the workers had a moderate (positive) attitude towards risk prevention from e-waste hazards, with an average score of  $30.02 \pm 3.84$ . This suggests that they were already prepared to protect themselves from hazardous substance exposure. However, item 1 had the lowest score, indicating that workers believed handwashing after work was sufficient for preventing disease. Therefore, to ensure that workers understand and practice appropriate handwashing practices, continuous hand hygiene training needs to be provided (Piližota, 2014). Conversely, a high score and adequate attitude response in item 8 indicated that they were typically worried that wearing a face mask while working would assist in preventing disease. Nonetheless, as previously mentioned, they lacked knowledge about the proper application and function of different kinds of masks.

After the training, our results found that the knowledge of workers was significantly improved from a moderate to a good level, suggesting the effectiveness of the active learning intervention on enhancing knowledge regarding risk prevention from e-waste hazards. For the attitude improvement, the average attitude score of workers showed significant, although little, differences between pre-training and post-training scores, which was not surprising given that higher increasing attitudes are unlikely to occur in a short period of time. Attitudes are relatively permanent and take time and effort to change (Jaworski et al., 2022). The increasing of knowledge and attitude aligns with findings from several studies that emphasize the importance of education in enhancing understanding of occupational hazards of workers. For example, Tabash et al. (2016) found that poor knowledge levels (50%) of healthcare workers detected in the pre-intervention stage were significantly raised to satisfactory levels (75%). They also found that educational programs significantly improved the practice and attitude of healthcare workers. In addition, Melo e Lima et al. (2018) found that the intervention group had significant improvements in overall KAP scores of community health workers in northeastern Brazil. Moreover, the role of educational programs was not only to enhance the KAP of workers in hazardous substances but also in several other aspects (Larki et al., 2015; Moreira et al., 2018; Rahman et al., 2018). To summarize, such an active learning intervention has proved effective in enhancing not only knowledge but also attitudes regarding practicing safety precautions.

On the other hand, despite the promising short-term results, we acknowledge that lasting behavioral changes are difficult to achieve without sustained interventions. A review study suggested that although improvement in knowledge and behavior following interventions was

generally reported, some reported that improvements in knowledge were not a change in behavior (Toivonen et al., 2017). Based on the knowledge, attitude, and behavior change model, behavior change occurs gradually and requires continuous motivation. Knowledge accumulation leads to attitude changes, which eventually result in behavior changes (Baranowski et al., 2003). Such concerns must be addressed on a regular basis by ensuring that knowledge and attitudes continue to improve through continuing community-driven educational programs to achieve long-term gains in worker health behaviors.

### **Strengths and Limitations**

This study was conducted as part of a project to explore the environmental and human impact of e-waste dismantling areas. The issues identified prompted the development of an educational program aimed at mitigating health risks among e-waste dismantling workers. The intervention was developed by offering active learning approaches, involving logical reasoning, and demonstrating information on good and inadequate facts to encourage participants to make educated decisions. The intervention was shown to be effective in increasing worker knowledge and attitudes, which can be used as guidance and further developed to respond to the continuing rise in e-waste.

A key limitation of this study is that we only provided active learning interventions to workers at a single time point. To acquire and sustain knowledge and attitudes, future programs should involve continuous implementation and follow-up to result in significant behavioral changes.

### **Conclusion**

This study demonstrated that active learning intervention significantly improved the knowledge and attitudes of e-waste dismantling workers regarding risk prevention from the e-waste hazards. The findings highlight the effectiveness of active learning activities. According to observations made during the activities, participants were very cooperative and eager to try the activities, particularly the activity of becoming aware of fluorescent substances on their hands as a result of handwashing residue. As a result, it is clear that any activity that clearly depicts dangerous situations or risks attracts the interest and cooperation of workers. However, the worker had some self-protective attitudes but lacked access to some expensive PPE. As such, it is critical to find a way to study and research access to such equipment, particularly the effectiveness of alternative PPE, such as using cloth masks in conjunction with surgical masks rather than N95 masks. Given these results, continuous education, access to alternative protective equipment, and workplace policies supporting long-term behavioral change are essential.

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### **Conflicts of Interest**

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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Table S1 Number of participants with correct answers in knowledge assessment

| No. | Question  | Pre- test<br>n (%) | Post- test<br>n (%) |
|-----|---|--------------------|---------------------|
| 1.  | Latex gloves can protect against weak acids.                                      | 10(10.10)          | 37(37.37)           |
| 2.  | Latex gloves can protect against all kinds of chemicals.                          | 27(27.27)          | 75(75.76)           |
| 3.  | Nitro gloves can't protect against thinners.                                      | 29(29.29)          | 35(35.35)           |
| 4.  | Chemical-resistant gloves can protect against all kinds of chemicals.             | 20(20.20)          | 28(28.28)           |
| 5.  | Cloth masks can protect against dust and chemicals.                               | 21(21.21)          | 70(70.71)           |
| 6.  | N95 masks can protect against dust and chemicals.                                 | 7(7.07)            | 50(50.51)           |
| 7.  | Masks with an activated carbon filter can protect against all types of chemicals. | 17(17.17)          | 28(28.28)           |
| 8.  | Masks with an activated carbon filter can also protect against dust.              | 96(96.97)          | 99(100.00)          |
| 9.  | Sitting and working can affect the lumbar spine.                                  | 94(94.95)          | 98(98.99)           |
| 10. | Sitting and working can affect the spine in the neck.                             | 88(88.89)          | 95(95.96)           |
| 11. | Pain from working is usually associated with older persons.                       | 71(71.72)          | 75(75.76)           |
| 12. | Sleep does not affect the spine.  | 52(52.53)          | 58(58.59)           |

Table S2 Number of participants with adequate attitude in attitude assessment

| No. | Question  | Pre- test<br>n (%) | Post- test<br>n (%) |
|-----|---|--------------------|---------------------|
| 1.  | Hand washing after work effectively prevents disease.                                       | 16(16.16)          | 35(35.35)           |
| 2.  | Chemicals frequently enter the body through pathways other than the hands.                  | 89(89.90)          | 87(87.88)           |
| 3.  | Long periods of hand washing with soap are a waste of time.                                 | 65(65.66)          | 76(76.77)           |
| 4.  | Most illnesses are caused by inhaling germs.  | 21(21.21)          | 22(22.22)           |
| 5.  | Wearing a face mask is hot and uncomfortable for working.                                   | 45(45.45)          | 61(61.62)           |
| 6.  | Waste dismantling jobs are unlikely to expose workers to chemicals through breathing.       | 54(54.55)          | 65(65.66)           |
| 7.  | Face masks are costly to purchase.  | 70(70.71)          | 75(75.76)           |
| 8.  | Wearing a face mask while working can help prevent illness.                                 | 91(91.92)          | 85(85.86)           |
| 9.  | I tend to prioritize ease of work over proper posture.                                      | 29(29.29)          | 23(23.23)           |
| 10. | When I have back pain, I believe regular massages can help.                                 | 34(34.34)          | 40(40.40)           |
| 11. | Sitting on the floor and working can result in paralysis.                                   | 56(56.57)          | 72(72.73)           |
| 12. | Simply avoiding lifting heavy objects can help reduce the risk of suffering from back pain. | 24(24.24)          | 28(28.28)           |

Note: Adequate attitude was defined as responding Strongly Agree or Agree to positively worded items and Disagree or Strongly Disagree to negatively worded items. The counts reflect the number of respondents meeting these criteria.