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Analysis and control of occupational safety risks using the HIRARC method in the Machining Workshop

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Abstract: This qualitative study focuses on occupational safety and health in vocational school machining workshops to identify significant risks related to training practices. Workplace accidents are considered a serious threat to workers and equipment, potentially affecting productivity and environmental safety. Observations at several vocational schools, especially at SMK Negeri 1 Batipuh, showed low student awareness and compliance with OHS regulations, increasing the risk of risky behaviour and accidents. To address this, the research used the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method, which systematically identifies hazards, evaluates risks based on severity and likelihood, and proposes control measures. The research at SMK Negeri 1 Batipuh involved direct observation, interviews, and analysis of SOPs in the workshop, finding significant risk variations in workshop conditions, lathe operations, welding, material handling, hand tool use, and machine protection. The results highlighted the predominance of intermediate risks in all-hazards analyzed, emphasizing the importance of developing more effective risk management strategies. This research aims to reduce accidents and improve student safety during training by addressing existing OHS implementation gaps and implementing appropriate risk controls. In addition to filling a gap in the literature, this study provides practical insights for improving OHS practices in vocational schools.

Keywords: Occupational safety and health; Quality education; Vocational education; Machining workshop

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1. Introduction

Occupational safety and health (OHS) are essential in industry and education, especially in high-risk environments such as machining workshops (Barati Jozan et al., 2023; Ismara et al., 2021). Workplace accidents are unwanted and unplanned events that can disrupt work, injure workers, damage equipment, and cause environmental damage. Accidents can happen anywhere, including vocational schools with practical activities and workshops. Machining engineering workshops, in particular, have a high potential risk of occupational accidents if not managed properly (Imad et al., 2022; Inderanata & Sukardi, 2023; Kumar et al., 2023).

Vocational High Schools (Indonesia: *Sekolah Menengah Kejuruan*/SMK) are educational institutions responsible for implementing work safety in the school environment per Law No. 1 of 1970 concerning Occupational Safety (Prasetya et al.,

2024; Rahim et al., 2024). As an educational institution that prepares students to enter the workforce, SMKs are responsible for creating a safe and healthy learning environment. This includes implementing strict standard operating procedures (SOPs) in every practical activity in the workshop, providing adequate personal protective equipment (PPE), and educating students and staff on OHS principles that must be adhered to. Through these efforts, SMK supports students' academic growth and safeguards their well-being during the practical learning process (Haviland & Robbins, 2021; Muskhir et al., 2024).

However, based on observations at various SMKs, including SMK Negeri 1 Batipuh, it was found that many students still do not realize the importance of work safety and are not orderly in implementing OHS rules in the workshop. Some risky student behaviours, such as joking while working, lack of concentration, and haste in working, are often the leading causes of work accidents (Boydstun et al., 2023; Heaton et al., 2021; Heraghty et al., 2020). Further observations showed that schools often pay little attention to OHS aspects. Examples include the lack of OSH posters in the workshop, the absence of evacuation route instructions, the lack of regular machine maintenance, and the priority given to student attendance issues rather than OSH violations.

To overcome this problem, it is necessary to implement sound and integrated OHS risk management. The HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method is an effective method to analyze and control occupational safety risks. The HIRARC method starts with the identification of potential hazards (Hazard Identification), then proceeds with a risk assessment to determine the likelihood and severity of the hazard, and ends with risk control to eliminate or reduce the risk based on prioritization (Chen et al., 2021; La Merrill et al., 2020; Wong et al., 2022).

This study aims to analyze and control work safety risks in the machining engineering workshop using the HIRARC method. Identifying potential hazards, assessing existing risks, and implementing effective control measures are expected to reduce the number of work accidents and improve student safety during practical activities. The absence of similar research at SMK Negeri 1 Batipuh is also an essential reason for conducting this research, as it can make a meaningful contribution to improving the application of OHS in the vocational education environment.

2. Methods

This qualitative research uses a descriptive approach and aims to analyse hazards and their prevention efforts in the SMK Negeri 1 Batipuh machining engineering workshop. The research was conducted in the even semester, from January to June 2024, in the machining engineering workshop of SMK Negeri 1 Batipuh. Data collection techniques used include direct observation, interviews, and analysis of SOP documents owned by the workshop. Primary data was obtained through observations in the workshop and during student practicum and interviews with teachers, students, and the head of the machining engineering expertise program. Secondary data was obtained by analyzing SOP documents in the school workshop that became the research location (Alam, 2021).

The data analysis technique follows the Miles and Huberman model, which includes three stages: data reduction, data presentation, and conclusion drawing and verification (Adelia et al., 2020; Asipi et al., 2022). This research uses the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method. The first stage identified the hazards in the workshop's conditions and the student practicum process. Next, the hazards were assessed by referring to the severity, frequency of occurrence, and risk ranking tables. After that, hazard control is determined based on the control hierarchy consisting of elimination, substitution, engineering control, administrative control, and the use of personal protective equipment (Ajslev et al., 2022; Song et al., 2020). The research results have also been verified by the machining technique teacher of SMK Negeri 1 Batipuh.

Figure 1. HIRARC (Hazard Identification, Risk Assessment, and Risk Control) Method

The severity value describes the level of danger caused by the work accident, which is categorized on a scale of 1-5. The following is a table of severity.

Table 1. Severity value

Level	Criteria	Description
1	Insignificant	The incident did not cause any injury to workers, and there was no loss.
2	Minor	The incident had no significant/profound impact and caused only minor injuries.
3	Moderate	The incident caused moderate financial loss; the worker was hospitalized but not disabled.
4	Major	The incident will result in severe injuries and injuries, permanent injuries and cause serious financial losses and serious consequences.
5	Catastrophic	Incidents can cause loss of life as well as severe losses that can stop work forever.

The likelihood level will indicate the likelihood of a work accident occurring, categorized on a 1-5 scale. More details are presented in Table 2.

Table 2. Likelihood value

Level	Criteria	Description
1	Rare	Very rarely occurs
2	Unlikely	The likelihood of occurrence is relatively small
3	Possible	Not often, but it may occur at any time
4	Likely	Occurs several times in a given time
5	Almost Certain	It happens all the time

Once the severity and likelihood values have been determined, the next step is to assess the hazard risk using the assessment matrix table. The results of this assessment will categorize the risks into low, medium, high, or extreme categories (Abe & Ozawa, 2020). The accident risk analysis in this study refers to the AS/NZS 4360:1999 standard.

Table 3. HIRARC assessment matrix

Likelihood	Consequences				
	1 (Insignificant)	2 (Minor)	3 (Moderate)	4 (Major)	5 (Catastrophic)
5: Almost Certain	M (5)	H (10)	E (15)	E (20)	E (25)
4: Likely	M (4)	H (8)	H (12)	E (16)	E (20)
3: Possible	M (3)	M (6)	H (9)	H (12)	E (15)
2: Unlikely	L (2)	M (4)	M (6)	H (8)	H (10)
1: Rare	L (1)	L (2)	M (3)	M (4)	M (5)

E = EXTREME (15-25): These actions require specialized planning from top management and immediate emergency handling. H = HIGH (8-14): Requires quick action from the manager for handling and repair. M = MODERATE (3-7): Perlu penanganan segera tanpa melibatkan manajemen puncak. L = LOW (1-2): Actions can be handled with existing routine procedures.

3. Results and discussion

The risk assessment of activities in the SMK Negeri 1 Batipuh machining workshop considers six main aspects: workshop conditions, turning practice, welding practice, material handling, and storage, use of hand tools, and machine guarding. The results of this study identified high, medium, and low-risk levels based on evaluating these six aspects (Elsharkawy, 2024; Kingwan et al., 2024). Here are the results and risks that have been identified.

3.1 Workshop condition of hazard assessment results

From the workshop condition evaluation results, it was found that 50% of the risks were rated as low, while the other 50% were in the medium risk category. The workshop condition hazard assessment identified no high or extreme risks, as shown in Figure 2.

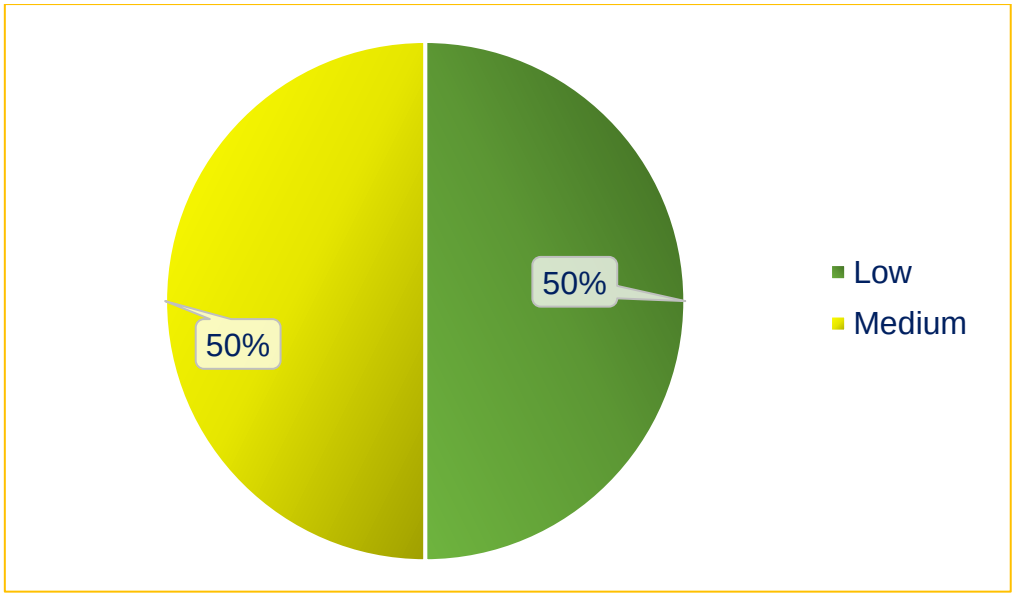

Figure 2. Hazard risk level workshop condition

3.2 Hazard assessment results of turning practicum

From the evaluation of the workshop conditions, it was found that 45% of the risks were rated as low and 55% as medium risks, with no high or extreme risks. Details of the hazard assessment results for the turning practical can be seen in Figure 3.

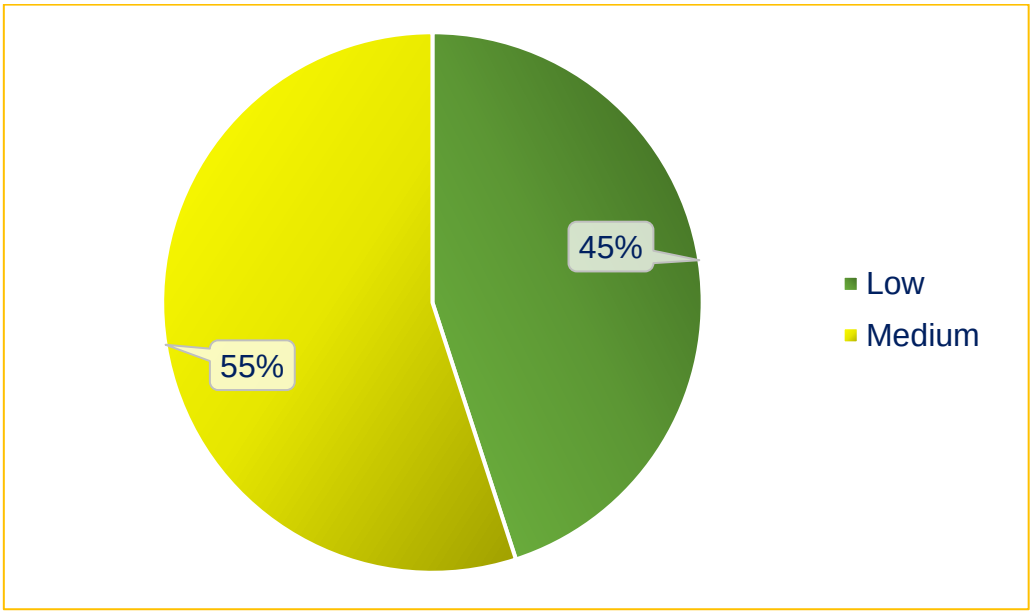

Figure 3. Risk level of turning practicum hazards

3.3 Hazard assessment results of the Welding Practicum

The workshop conditions' evaluation found that 44% of the risks were rated as low and 44% as medium, while high risks accounted for 12% with no extreme risks. Details of the hazard assessment of the welding practicum are shown in Figure 4.

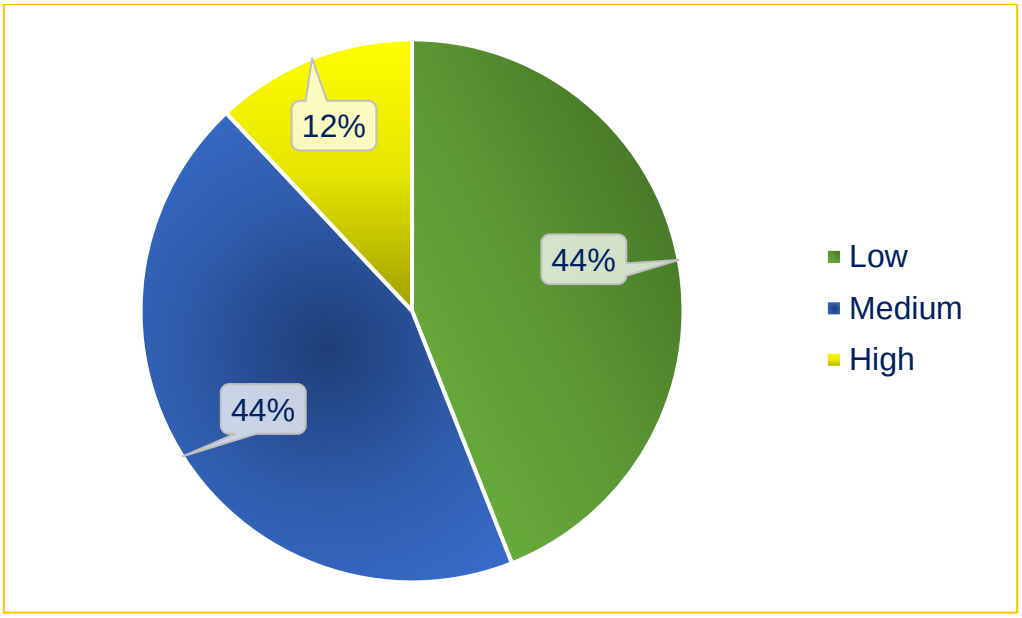

Figure 4. Risk level of welding practicum hazards

3.4 Assessment results of material handling and storage

The evaluation of material handling and storage found that 44% of the risks were rated as low and 44% as medium risk, with high risk reaching 12% without any extreme risk. Details of the material handling and storage hazard assessment are presented in Figure 5.

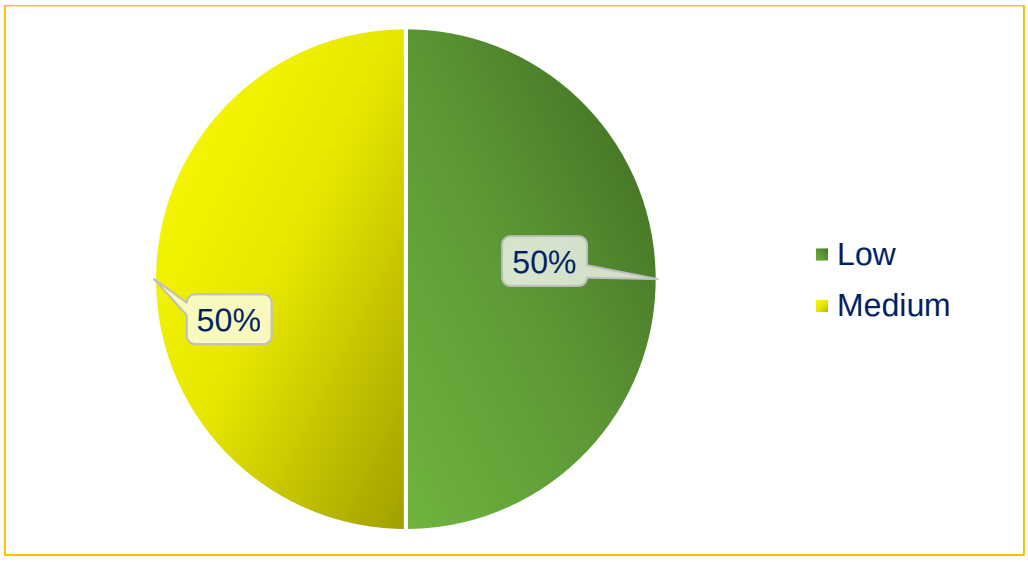

Figure 5. Risk level of material handling storage hazards

3.5 Hazard assessment results of hand tool use

The assessment of hand tool use found that 38% of the risks were rated as low and 62% as medium risk, with no high or extreme risks. The detailed results of the hand tool use hazard assessment are shown in Figure 6.

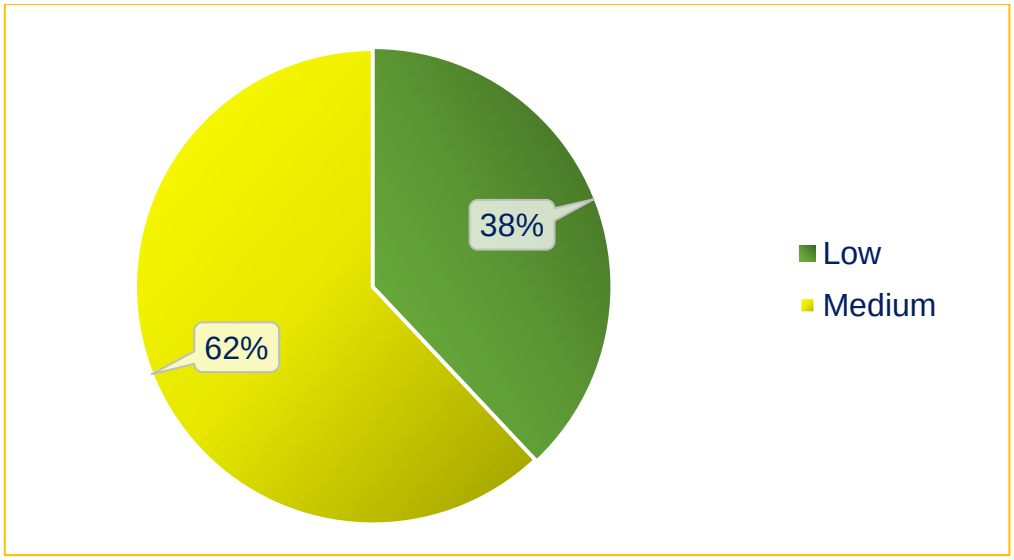

Figure 6. Risk level of hand tool use hazards

3.6 Hazard assessment results of machine guarding

The machine guarding evaluation found that 29% of the risks were rated as low and 71% as medium risk, with no high or extreme risks. Details of the assessment results regarding machine guarding hazards can be seen in Figure 7.

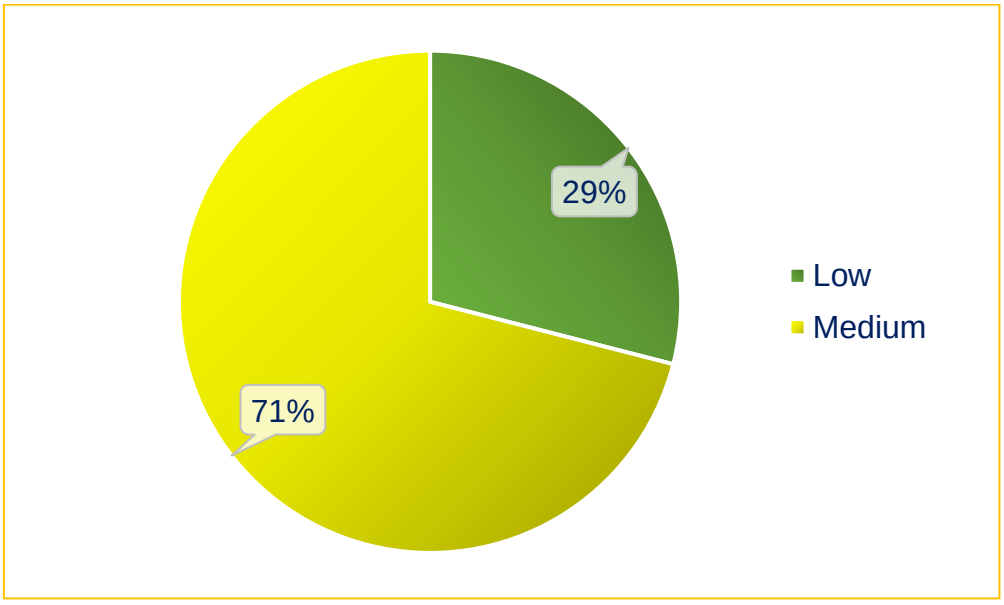

Figure 7. Machine Guarding Hazard Risk Level

3.7 Discussion

The results align with previous research highlighting significant safety risks in vocational school workshops (Barati Jozan et al., 2023; Ismara et al., 2021). This study identified a lack of student awareness and compliance with OHS regulations as major contributing factors. The predominance of medium-level risks suggests that while some safety measures are in place, there is substantial room for improvement

(Kjestveit et al., 2021). Consequently, enhancing safety training programs, improving equipment maintenance, and increasing the visibility of safety signage are critical steps toward reducing these risks and fostering a proactive safety culture.

This research underscores the necessity for robust safety training programs that emphasize adherence to OHS guidelines (Lari, 2024; Schulte et al., 2022). Regular equipment maintenance and inspection are crucial for mitigating machinery-related risks. Enhancing the visibility and clarity of safety signage within workshops can reinforce protocols and reduce risky behaviors among students. Integrating a culture of safety within the curriculum fosters a proactive approach to OHS, encouraging students to prioritize safety in all workshop activities (Chatigny, 2022; Kavouras et al., 2022). Establishing partnerships with industry professionals can provide vocational schools with up-to-date knowledge on best practices and emerging safety technologies, ensuring that safety measures are both current and effective (Akinlolu et al., 2022; Che Ibrahim et al., 2022; Hernandez-de-Menendez et al., 2020).

Furthermore, fostering a culture of safety through continuous education and awareness campaigns can help ingrained OHS principles in the daily practices of students and staff (Bisbey et al., 2021). Collaboration with industry partners can provide valuable insights into best practices and emerging technologies in occupational safety, facilitating the sharing of resources and expertise, and helping vocational schools stay updated with the latest OHS standards. These steps are essential for creating a safer educational environment, reducing the occurrence of accidents, and enhancing the overall safety culture in vocational education settings.

4. Conclusion

This study highlighted the significant occupational safety and health (OHS) risks present in the machining workshop of SMK Negeri 1 Batipuh. Using the HIRARC method, the research identified that many activities in the workshop exhibit medium-level risks, primarily due to a lack of student awareness and compliance with OHS regulations. While some safety measures are currently in place, there is considerable scope for improvement. Enhancing safety training programs, increasing regular equipment maintenance, and improving the visibility of safety signage are crucial steps to mitigate these risks. Additionally, fostering a culture of safety through continuous education, integrating OHS into the curriculum, and establishing partnerships with industry professionals can ensure that vocational schools maintain current and effective safety measures. These findings underscore the need for systematic risk management to reduce accidents and promote a safer learning environment.

Future research should focus on developing and evaluating comprehensive safety training programs tailored to the specific needs of vocational school students. Longitudinal studies assessing the effectiveness of these training programs on improving student compliance with OHS regulations and reducing accident rates would provide valuable insights. Additionally, exploring the integration of advanced safety technologies, such as real-time monitoring systems, could further enhance safety measures in vocational workshops. Collaboration with industry partners to stay updated on best practices and emerging safety technologies should also be pursued. Finally, expanding this research to other vocational schools can help identify common challenges and successful strategies for improving OHS practices in vocational education settings nationwide.

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Declarations

Author contribution

Roki Putra Anwar: Experiment, Anylisys VosViewer, dept-review and write original articles. Andre Kurniawan: Data Curation, Writing - Review & Editing, and Supervision. Mulianti: Writing - Review & Editing, and Supervision. Zainal Abadi: Writing - Review & Editing, and Supervision.

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Competing interest

The authors declare no conflict of interest in this study.

Ethical Clerance

This research has been approved by the West Sumatra Education Office with letter number 420.02/0343/PSMK-2024 and has been approved by the school of SMK Negeri 1 Batipuh with letter number 432/195/ SMK.01-BTP/2024. Students who are respondents for this study have previously agreed to participate in this study. The research was conducted in accordance with the Declaration of Helsinki.

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