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Differences in Knowledge Levels in Providing Online Fire Simulations and Offline Fire Simulations at a Steel Manufacturing Company in Semarang

Zahra Nurdina Fitriani[1*], Yuliani Setyaningsih[2], Hanifa Maher Denny[3]

[1]Fakultas Kesehatan Masyarakat, Universitas Muhammadiyah Semarang
[2,3] Fakultas Kesehatan Masyarakat, Universitas Diponegoro

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ABSTRACT

Introduction: Iron and steel manufacturing companies have a high potential for fire hazards because their production processes use temperatures above 400°C. Therefore, the ability of workers to reduce fire risks and respond to fire emergencies is essential. **Methods:** This study is a quantitative study with a quasi-experimental method using a pre-test and post-test design. The study was conducted in June 2021, involving 50 workers divided into two groups. The first group received online fire simulation training, while the second group received offline fire simulation training. Both groups completed pre-test and post-test questionnaires. Data analysis was performed using non-parametric statistical tests, namely Wilcoxon Signed Ranks test and Mann–Whitney test. **Results:** The results showed a difference in knowledge levels before and after the simulation in both groups ($p < 0.05$). However, the increase in knowledge in the offline simulation group was higher than in the online simulation group. These findings indicate that offline fire simulations are more effective in increasing workers' knowledge than online simulations. **Conclusion**: Companies are advised to prioritize offline fire simulations in order to obtain optimal learning outcomes.

Corresponding Authors: (*)
Prodi Kesehatan Masyarakat, Fakultas Kesehatan Masyarakat, Universitas Muhammadiyah Semarang, Jl. Kedungmundu Raya No. 18, Kota Semarang, Jawa Tengah 50273, Indonesia
Email: zahranurdina@unimus.ac.id

INTRODUCTION

One indicator of a country's economic strength is the performance of its iron and steel industry. Iron and steel play an important role in infrastructure development and the manufacturing sector, where around 95% of the metal equipment used by humans comes from iron and steel materials (World Steel Association, 2025).

Fire hazards can occur in various industrial environments. Based on the latest NFPA data in the Fire Loss in the United States During 2023 report, it is estimated that approximately 1.39 million fire incidents occurred in the United States that year, resulting

in approximately 3,670 deaths, 13,350 injuries, and economic losses reaching ±USD 23 billion (Hall, 2025). This figure reflects the significant trend of the impact of fires in the US, although compared to the previous decade there has been a shift in the structure of economic losses. Based on the Decree of the Minister of Manpower of the Republic of Indonesia Number 186/MEN/1999 concerning Fire Fighting Units in the Workplace, the steel industry is classified as a workplace with a medium fire potential (Medium II), due to the accumulation of materials and production processes that generate heat sources (Indonesian Manpower Decree: KEP.186/MEN/1999, 1999).

Based on data from the Central Java Provincial Statistics Agency (BPS), fires are recorded as one type of natural disaster that occurred in the province in the 2024 period (Semarang City Statistics Agency, 2024). This shows that fires still occur periodically in various regencies and cities, with varying degrees of material damage. To minimize the risk of fire, it is necessary to implement occupational safety and health management that includes hazard identification, risk assessment, risk control, and continuous monitoring and evaluation (El et al., n.d.).

The iron and steel industry has a significant risk of fire due to high-temperature production processes and the accumulation of flammable materials. Recent research confirms that fire simulation is an effective method for improving workers' knowledge and preparedness. Several studies in the last five years have shown differences in effectiveness between online and offline training, particularly in improving cognitive aspects and practical skills (Safril et al., 2023) found that online training effectively improves participants' knowledge and attitudes, but is less optimal in improving technical skills due to limitations in hands-on practice. Research (Musawirin et al., 2023) also shows differences in learning outcomes between fully online and blended learning methods, with face-to-face combinations yielding better results. Empirical evidence regarding the effectiveness of online-based simulations, particularly in the iron and steel industry, is still limited. In addition, comparative studies between online and offline fire simulations in the context of industries with moderate to high fire risk have not been widely conducted (Li et al., 2023).

This study aims to analyze the differences in workers' knowledge levels between online fire simulations and offline fire simulations in the iron and steel manufacturing industry.

LITERATURE REVIEW

Worker knowledge is one of the main determinants of preparedness for fire emergencies in the workplace. According to the Knowledge–Attitude–Practice (KAP) theory, increasing knowledge through educational interventions will influence attitudes and ultimately encourage better safety behavior. In the context of occupational safety and health (OSH), knowledge about sources of danger, evacuation procedures, and the use of fire extinguishers (APAR) is an important basis for workers' preparedness in responding to fire incidents (Lituhayu Liyudza Dwiagda Maheswari, 2025) (Andrianto et al., 2022).

Fire simulation is an experiential learning method that aims to improve knowledge and preparedness by simulating emergency conditions that closely resemble real-life situations. Offline fire simulations allow workers to be directly involved in field practice, use actual equipment, and receive direct feedback from instructors. This approach is considered effective in improving workers' procedural understanding and motor skills in dealing with fire emergencies (Ariyanti et al., 2023; Lukman & Muhammad, n.d.).

However, offline simulations have limitations, including relatively high costs, time constraints, and the potential to disrupt company production processes (Li et al., 2023). With the development of information technology, online fire simulations have been

developed as an alternative method of occupational safety and health training. Online simulations utilize digital media such as interactive videos, online modules, and virtual scenarios that enable the flexible and efficient delivery of fire safety material (Lavoie et al., 2025) (Naomi Tutticci et al., 2024).

Based on this theoretical framework, this study uses fire simulation types (online and offline) as independent variables and workers' knowledge levels as dependent variables. The research framework is based on the assumption that different simulation methods will result in different levels of knowledge improvement, thus requiring a comparative study to determine the most effective method for the iron and steel manufacturing industry, which has a high risk of fire (Medika Jurnal et al., 2024).

METHODS

This study used a quasi-experimental design with a pre-test and post-test design. The study was conducted in June 2021 with 50 active workers in the production department as research respondents, selected using purposive sampling with the following criteria: active workers, ≥1 year of service, and no fire simulation training in the last 6 months.

The research instrument was a questionnaire based on the fire safety standards of the National Fire Protection Association (NFPA). The fire knowledge variable consisted of 10 multiple-choice questions and was tested for validity with a value of α=0.05 and reliability with a value of α=0.07. Respondents were divided into two groups, namely online and offline fire simulation.

Data collection was conducted through simulations according to each group. The online simulation group used Zoom meetings, while the offline simulation group was conducted by the presenter using firefighting equipment directly. Data analysis used the Wilcoxon test to determine the difference between the pre-test and post-test, as well as the Mann–Whitney test to compare the two groups. Bias was minimized by standardizing the material, duration of intervention, and measurement instruments. The research instrument consisted of 10 multiple-choice knowledge items with a dichotomous scoring system for knowledge level using a cut-off of ≥75% (good), 56–74% (fair), and <55% (poor). This instrument was used in the pre-test and post-test to measure changes after the online simulation and practice interventions.

RESULTS AND DISCUSSION

The respondents were predominantly male, with 46 participants (92%), while females accounted for 4 participants (8%). In terms of education, most respondents had completed senior high school (38%), followed by diploma (30%) and bachelor's degree (24%). Only a small proportion had junior high school (6%) or elementary school education (2%). This indicates that the majority of respondents had at least a secondary education level (Table 1).

Table 1. Respondent's Characteristics

Gender	Categories	Frequency (n)	Percentage (%)
Gender	Female	4	9
	Male	46	92
Education	Elementary School	1	2
	Junior High School	3	6
	Senior High School	19	38
	Diploma	15	30
	Bachelor's Degree	12	24

The results showed an improvement in participants' knowledge following both online and offline simulations. In the online simulation group, the proportion of participants with good knowledge increased from 52% during the pre-test to 60% during the post-test, while the mean score increased from 7.12 to 8.56. Similarly, in the offline simulation group, the proportion of participants with good knowledge increased from 36% to 52%, accompanied by an increase in the mean score from 7.24 to 9.40. These findings indicate that both simulation methods contributed to improving participants' knowledge, with a greater increase in mean scores observed in the offline simulation group (Table 2).

Table 2. Distribution of Pre-Test and Post-Test Scores in Online and Offline Simulation

Variables	Categories	Pre-test			Post-test		
		n	%	Mean	n	%	Mean
Knowledge from online simulation	Good	13	52	**7.12**	15	60	**8.56**
	Bad	12	48		10	40	
Knowledge from offline simulation	Good	9	36	**7.24**	13	52	**9.40**
	Bad	16	64		12	48	

Note: n= frequency; %= percentage

When viewed individually, the majority of respondents experienced an increase in their scores (positive gain score). Only a small proportion showed minimal or relatively stable improvement (Figure 1).

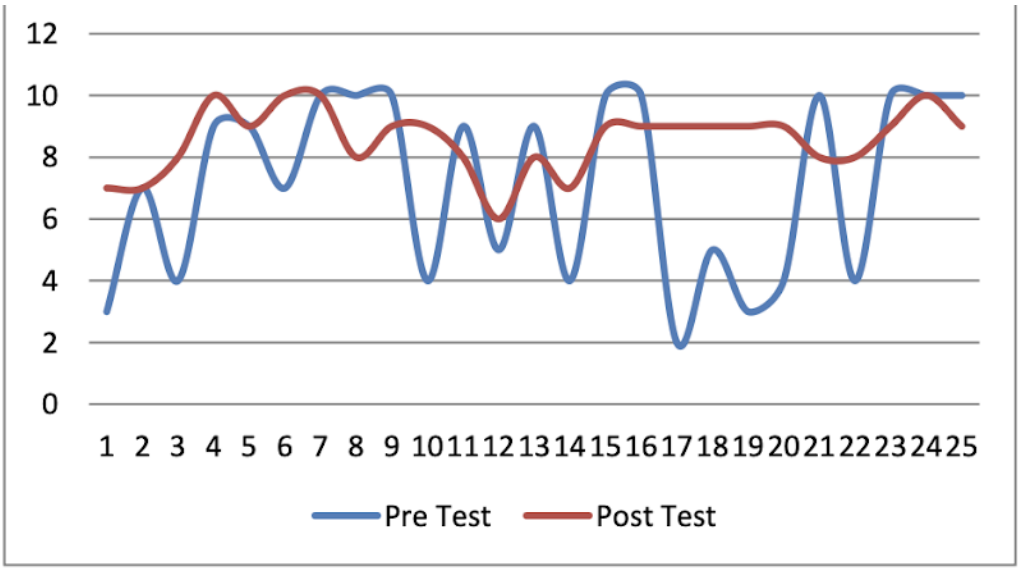

Figure 1. Changes in Online Group Knowledge Scores

The gain score calculations showed that most respondents experienced an increase in their knowledge scores after the intervention. The average gain score was in the positive category, indicating an overall increase in understanding. No significant decrease in scores was found among respondents, indicating that the intervention was effective in increasing knowledge levels (Figure 2).

The normality test on the research sample was conducted to determine whether the data came from a normally distributed population, using the Kolmogorov–Smirnov test and the Shapiro–Wilk test. Because the sample size in this study was less than 100, the Shapiro–Wilk test was used as a reference to determine data normality. At a significance level of 0.05, the testing criteria using the Shapiro–Wilk test are as follows: if the Sig. value

is > 0.05, then H_0 is accepted, which means that the sample comes from a normally distributed population; conversely, if the Sig. value is ≤ 0.05, then H_0 is rejected, which means that the sample comes from a non-normally distributed population (Table 3).

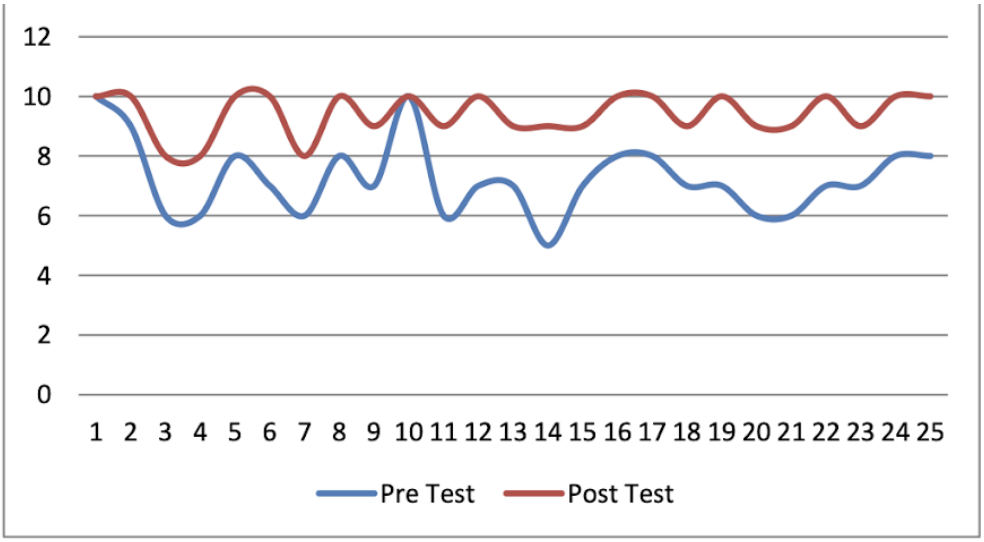

Figure 2. Offline Group Knowledge Score Changes

Table 3. Results of the Normality Test

Variables	Test	Groups	Shapiro-Wilk		
			Statistic	df	Sig.
Knowledge	*Pre-test*	Online Simulation	.815	25	.000
		Offline Simulation	.909	25	.028
	Post-test	Online Simulation	.889	25	.011
		Offline Simulation	.752	25	.000

The Wilcoxon Signed Ranks Test (WRS) was used to determine differences before and after the intervention in each group. A result is considered significant if the significance value is less than 0.05 ($\alpha < 0.05$). Based on the results shown in Table 1.6, the level of knowledge of respondents in the offline simulation group showed a more significant difference compared to the online simulation group (Table 4).

Table 4. Difference Test Table

Category	Z	Sig. (2-tailed)
Knowledge (Pre-test – Post-test) Online Simulation	-2.089[b]	.037
Knowledge (Pre-test – Post-test) Offline Simulation	-4.327[b]	.000

The results of this study indicate a difference in scores between conditions before and after the implementation of online and offline simulations on the variables of knowledge level and simulation role. Overall, the data indicate that most respondents experienced an increase in scores after the simulation implementation. This finding supports the notion that the use of digital-based simulations has a positive effect on respondents' learning process, particularly in the cognitive (knowledge) and affective

(attitude) aspects, as well as preparedness and understanding of the roles that must be carried out within the given simulation context.

Table 5. Non-Parametric Test Results of Pre-test and Post-Test

Variables	Z	Sig. (2-tailed)
Knowledge Pre-test online simulation and offline simulation	-.344	.731
Knowledge Post-test online simulation and offline simulation	-3.022	.003

This research aligns with the results of a quasi-experimental study by Surya and Afrizal (2025), which stated that online simulation methods effectively improved student competency in the context of family nursing practice, as indicated by an increase in psychomotor and decision-making competency scores (competency gain) after the online simulation intervention. These results were significant with a p value <0.05, thus strengthening the influence of online simulation methods on the competency achievement of study participants (Oka Surya et al., 2021).

Transformation of occupational safety training through e-learning. A review of the literature shows that online training has advantages in terms of time flexibility, cost efficiency, and cross-regional accessibility. However, its effectiveness is more dominant in improving cognitive knowledge than practical skills that require direct simulation (Daniel O. Badea, 2024). The consistency of these research results is also evident in the context of using interactive simulation media for clinical skills. Susila and Laksmi (2025) found that interactive multimedia simulations can improve nursing students' CPR skills and self-efficacy, indicating that digital simulations not only have an impact on increasing knowledge but also on the practical aspects and confidence of participants (Medika Jurnal et al., 2024).

Although the majority of respondents experienced an increase, this study also noted that some respondents obtained the same or even lower scores in terms of knowledge after the online simulation. This shows that the effectiveness of online simulations is not universal and can be influenced by other factors. Several previous studies have mentioned that limited two-way interaction, lack of direct feedback, and technical constraints such as internet network quality can be obstacles in the online learning process, so that some participants did not achieve the expected score improvement (Shidiq & Zulaikha, 2024). Stout found in his study that online training participants experienced certain obstacles in participating in learning activities, which had an impact on suboptimal learning outcomes. These findings are consistent with the results of this study, which show that there are respondents whose post-test scores did not increase (Stout et al., 2012).

Various studies have shown that the effectiveness of virtual simulations depends on the context and learning design. Research outside the healthcare field has found that virtual simulations can significantly improve conceptual understanding compared to non-simulation methods when properly designed (Naomi Tutticci et al., 2024). In this study, all respondents also experienced improved scores on the role aspect after participating in the online simulation, indicating that structured scenarios and clear task allocations helped participants understand their responsibilities more deeply (Oka Surya et al., 2021; Suparmanto et al., 2024).

In general, online simulations have proven effective in improving knowledge, attitudes, preparedness, and role understanding, especially when face-to-face learning is

limited. However, their success remains influenced by pedagogical and technical factors, requiring interactive feedback, enhanced collaboration, and management of technical constraints to optimize learning outcomes (Hudder et al., 2021; Lawn et al., 2017; Zahra Nurdina Fitriani et al., 2022).

CONCLUSION

There was a difference in the respondents' knowledge levels before and after the online simulation, with average scores of 7.12 and 8.56, respectively. In addition, the difference in knowledge levels before and after the offline simulation showed average scores of 7.24 and 9.40 at PT X Semarang. The results of this study indicate a difference in the level of knowledge of respondents between the online simulation and offline simulation groups, with significance values of 0.037 and 0.000, respectively.

Based on the results of the study, it can be concluded that offline fire simulations are proven to be more effective in improving participants' knowledge, attitudes, preparedness, and understanding of their roles compared to online simulations, due to the direct experience and real interaction in the use of equipment and the application of emergency response procedures. However, online-based simulations can still be used as a useful complementary method, especially in conditions where there are limitations in terms of time, cost, or face-to-face access. With a structured design and adequate technical support, online simulations can still make a positive contribution to strengthening participants' understanding and preparedness.

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