

A Study on the Training Effectiveness of Safety Practical Course for Safety Supervisor in the Petrochemical Industry

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ABSTRACT

This study aims to assess the effectiveness of practical safety training courses for safety supervisors in the petrochemical industry. The petrochemical industry is characterized by high capital and technology intensity, significant resource dependency, substantial economies of scale, a broad range of products, an extensive downstream market, stringent environmental and safety requirements, and intense global competition. These characteristics define the industry's essential role in the economy and its operational model.

The industry's labor demands include technical skills, safety and environmental awareness, problem-solving abilities, teamwork, continuous learning, and effective time and stress management. These requirements underscore the technical complexity, high safety standards, and functional expectations of the industry. To meet these stringent safety needs, the training program incorporates real-world scenarios. A practical safety training facility has been established, equipped with diverse training tools, including scaffolding and fall protection for elevated work, cranes and rigging tools for lifting operations, digital display boards and retaining walls for civil engineering tasks, storage tanks and ventilation systems for confined space operations, pumps and explosion-proof tools for hot work, electrical testing panels, protective gear for water jet operations, personal protective equipment, and gas detectors.

For this study, ten years of big data from Company A were analyzed, with qualified trainees from the practical safety training courses for safety supervisors serving as the research subjects. The Kirkpatrick Four-Level Training Evaluation Model was used to analyze pre- and post-training effectiveness, with performance indicators including improvements in certification bonuses, frequency of audit irregularities, annual performance appraisals, and departmental annual evaluation scores.

The main findings of this study are as follows:

1. The practical safety training for safety supervisors has a significant positive impact on improving certification bonus, reducing the frequency of audit irregularities, and increasing annual performance appraisal and departmental annual evaluation scores, indicating that the course effectively enhances trainees' job performance and the department's safety management level.
2. Based on the results of this study, it is recommended that future training unit designs and teaching methods in practical safety training for safety supervisors include more discussions on practical work hazard scenarios, integrate findings from behavioral and cognitive science research, and apply information technology tools to increase trainee engagement and learning outcomes.

This study hopes to provide valuable references and improvement suggestions for practical safety training courses for safety supervisors in the petrochemical industry and offer useful insights for future research in related fields.

Keywords: Safety, Practical Training Courses, Training Effectiveness, Kirkpatrick Model, Certification Bonus, Audit Irregularities, Annual Performance Appraisal, Departmental Annual Evaluation

1. INTRODUCTION TO RESEARCH BACKGROUND

1.1 Research Background and Motivation

Production equipment in the petrochemical industry is essential for ensuring process stability, safety, and quality. Given the use of high-risk chemicals, safety supervisors must strictly enforce maintenance protocols and ensure that all operations comply with safety standards. This study will examine the effectiveness of Company A's safety implementation training course in enhancing the professional knowledge and skills of safety supervisors and evaluate the course's contribution to the company's goal of reducing industrial accidents.

1.2 Research Objectives

The purpose of this study is to assess the impact of the safety supervisors' training course on trainees at both the behavioral and outcome levels. Specifically, it aims to:

- 1) Evaluate the changes in trainees' performance regarding certification bonuses, audit irregularities, and annual performance appraisals after training.
- 2) Analyze the performance changes in trainees' department-level annual evaluations after training.

1.3 Research Questions

The following research questions are posed to achieve the research objectives:

- 1) Is there a significant change in the trainees' average annual performance at the behavioral level after completing the training?
- 2) Is there a significant change in the trainees' average annual performance at the outcome level after completing the training?

1.4 Definitions of Terms

To ensure clarity of concepts, the following key terms are defined:

- 1) Petrochemical Industry: Refers to industries that use petroleum and natural gas as raw materials to produce petroleum products and chemical products.
- 2) Safety Supervisor: A professional responsible for overseeing safe operations during construction processes and ensuring compliance with safety regulations.
- 3) Training Effectiveness: Refers to the changes in behavior and outcomes of safety supervisors after receiving training, as well as the impact on organizational performance.

1.5 Scope and Limitations

This study focuses on 548 safety supervisors from Company A's various facilities in Taiwan who have passed the safety implementation training course. As this study relies on secondary data analysis, caution must be exercised when generalizing the results, and the scope of the research is limited to Company A, excluding the training effects on other companies or industries.

2. LITERATURE REVIEW

2.1 Overview of Taiwan's Petrochemical Industry Development

Petrochemical Refining Industry Chain

The petrochemical industry in Taiwan began to develop in the 1960s, with the construction of the first light oil cracking plant marking its inception. With the rapid development of the plastics industry in the 1970s, the petrochemical industry gradually transitioned from the stage of importing raw materials for processing to the self-production of midstream and upstream raw materials, forming a complete industrial chain (Fair Trade Commission, 2021). The industrial safety and environmental incidents of the 1980s, coupled with the waves of globalization, drove the petrochemical industry toward diversification. This led to the launch of the Sixth Naphtha Cracker Project, which was completed in 2001 with the establishment of Formosa's Mailiao Petrochemical Complex (Liang & Zheng, 2014; Chen, 2016).

Overview of Taiwan's Petrochemical Production

Over decades of development, Taiwan's petrochemical industry has established a comprehensive production

system spanning the upstream, midstream, and downstream stages. The upstream processes involve the refining of raw materials such as light oil and gasoline; the midstream processes include chemical reactions to produce chemical raw materials like plastics and rubber; and the downstream processes further refine these materials into everyday products. Ethylene is a key raw material in the petrochemical industry, and its production volume is often used to gauge the development level of a country's petrochemical sector. Taiwan's major ethylene production companies have a combined annual output of 4.005 million tons, underscoring the industry's significance to the national economy.

2.2 Practical Training Theories

Behavioral Cognition

The foundational theory of behavioral science was proposed by Skinner (1938), who emphasized the impact of the environment on behavior. According to the "ABC Theory," the environment, acting as an "Antecedent," triggers specific behavior (Behavior), and the consequences (Consequences) of that behavior will further reinforce or modify it.

Learning Theory

Dale's (1946) Learning Pyramid Theory highlights that learning outcomes depend on the method of learning. Active learning modes, such as group discussions and hands-on practice, significantly enhance learning effectiveness.

2.3 Training Effectiveness Measurement Theory

Kirkpatrick's (1959) four-level evaluation model is the most commonly used framework for assessing training programs. It includes reaction, learning, behavior, and results levels. This model provides a comprehensive structure for evaluating the effectiveness of training programs.

3. RESEARCH METHODS AND DESIGN

The growth of an enterprise depends on talent cultivation, and the development and training of talent are key sources for enhancing corporate competitiveness. To meet the needs of different roles and close competency gaps, companies design comprehensive training programs. Effective corporate training methods can improve employees' skills and professional knowledge, leading to behavioral changes and the transmission of corporate culture. This study applies Kirkpatrick's four-level evaluation model to explore the effectiveness of the safety supervisors' training course before and after implementation. This chapter further explains the research framework, hypotheses, subjects, course design and implementation, research tools, research procedures, and data processing.

3.1 Research Framework

This study aims to evaluate the effectiveness of Company A's safety training program for safety supervisors in the petrochemical industry. The intervention variable in the research framework is the "Practical Safety Training Course for Safety Supervisors," while the dependent variables include behavioral performance (such as certification bonuses, audit irregularities, and annual performance appraisal) and outcome performance (such as departmental annual evaluation scores).

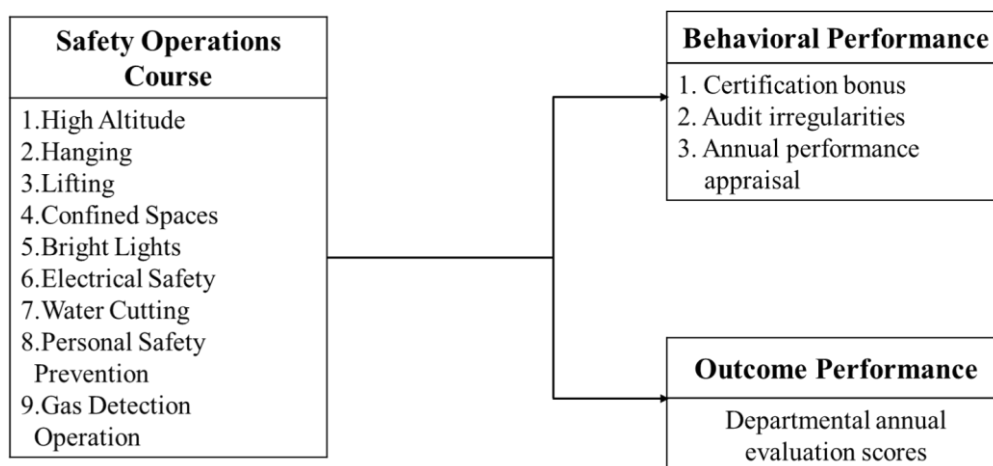


Figure 3-1 Research Framework Diagram

3.2 Research Hypotheses

Based on the research objectives and questions, the following hypotheses are proposed:

H1: There is a significant improvement in behavioral performance after trainees complete the course.

H1-1: Certification bonuses significantly increase.

H1-2: Audit irregularities significantly decrease.

H1-3: Annual performance appraisals significantly improve.

H2: There is a significant improvement in outcome performance after trainees complete the course.

H2-1: Departmental annual evaluation scores significantly increase.

3.3 Research Subjects

The subjects of this study are the safety supervisors in Company A’s petrochemical industry who participated in the practical safety training course and passed the evaluation between 2018 and 2020. A total of 548 employees participated, with 255 in 2018, 109 in 2019, and 184 in 2020. The research data were sourced from Company A’s ERP system, including information on certification bonuses, Audit irregularities, annual performance appraisals, and departmental annual evaluations scores.

3.4 Practical Course Design and Implementation

Company A designed the practical safety training course based on the competency needs of its safety supervisors, covering high-rise work, lifting operations, civil engineering operations, confined space work, hot work, electrical work, water jet operations, personal safety protection, and gas detection. The course aims to improve employees’ safety behaviors and ensure safe operations in their actual work environments.

4. RESULTS AND DISCUSSION

This chapter analyzes the differences in safety supervisors’ performance before and after the training using paired sample t-tests based on the research objectives and questions. The results are discussed in five sections: data description, data consolidation, basic data statistical analysis, training effectiveness analysis, and comprehensive discussion.

4.1 Data Description

This study collected data on trainees' personal information, certification details, training records, self-inspections, external audits, and regular work evaluation records.

Table 4-1 Basic description of data

Item	File Name	Number of Entries	Data Included	Time Period
1	Personal Basic Data	6,768	6,768	1983-2021

2	Certification Data	17,182	17,182	2014-2020
3	Training Records	736,622	736,622	2014-2020
4	Self-Inspections and External Audits	17,275	3,736	2004- 2021
5	Regular Work Evaluations	494,036	435,417	2014- 2021

4.2 Data Consolidation

Before analysis, all data were coded, cleaned, and consolidated based on employee identification codes. Table 4-2 presents the four main performance indicators and their descriptions.

Table 4-2 Data Consolidation

Item	Performance Indicator	Description
1	Certification Bonus	Summing individual scores by year based on certification levels
2	Audit Irregularities	Summing individual Audit irregularities by year
3	Annual Performance Appraisal	Summing individual annual performance scores (Excellent: 3 points, Good: 2 points, B: 1 point, C: 0 points)
4	Departmental annual evaluation scores	Summing departmental evaluation scores by year

4.3 Demographic Data Statistical Analysis

After performing frequency analysis on the trainees' demographic data, the distribution of the number of certified trainees is shown in Table 4-3.

Table 4-3 Statistical Distribution of Safety Supervisors

Year	2018	2019	2020	Total
Number of Certified Trainees	255	109	184	548

4.4 Training Effectiveness Analysis

In terms of behavioral performance, including certification bonuses, audit irregularities, and annual performance appraisal, the results indicate that post-training performance was significantly better than pre-training. Detailed data for each item are presented in Tables 4-4 to 4-6. For outcome performance, the departmental annual evaluation also shows a significant improvement in post-training performance, with detailed data provided in Table 4-7.

Table 4-4 Paired Sample t-Test for Certification Bonus Before and After Training (n=547)

Paired Variable	Mean	Standard Deviation	Mean Difference	t-Value	p-Value
Two-Year Post-Training Annual Average	1.483	2.363	0.752	6.563***	.000
Three-Year Pre-Training Annual Average	0.731	1.223			

***p<.001

The results of table 4-4 suggested that the training had a positive and statistically significant impact ($t=6.563$, $p<.001$) on the participants' certification bonuses. The increase in average (mean difference=0.752) bonuses post-training compared to pre-training strongly supports the effectiveness of the training program.

Table 4-5 Paired Sample t-Test for Audit Irregularities Before and After Training (n=547)

Paired Variable	Mean	Standard Deviation	Mean Difference	t-Value	p-Value
Two-Year Post- Training Annual Average	0.027	0.515	-0.121	-5.360***	.000
Three-Year Pre- Training Annual Average	0.148	0.834			

***p<.001

The data in table 4-5 strongly suggested that the training was effective in significantly reducing the frequency or severity of audit irregularities among the participants (t=-5.360, p<.001). The marked decrease in both the mean value of irregularities post-training and the standard deviation(mean=-0.121) points to the training's role in not only reducing irregularities but also making their occurrence more consistent and predictable among the participants. This underscores the training's effectiveness in enhancing practices or compliance in auditing contexts.

Table 4-6 Paired Sample t-Test for Annual Performance Appraisal Before and After Training (n=547)

Paired Variable	Mean	Standard Deviation	Mean Difference	t-Value	p-Value
Two-Year Post- Training Annual Average	0.982	0.366	0.168	12.110***	.000
Three-Year Pre- Training Annual Average	0.814	0.460			

***p<.001

The statistical data of table 4-6 strongly suggested that the training significantly improved the annual performance appraisal scores among the participants (t=12.110, p<.001). The marked increase in both the mean value(mean=0.168) of the appraisals post-training and the decrease in the standard deviation point to the training's role not only in enhancing appraisal scores but also in standardizing how performance is evaluated across participants. This underscores the effectiveness of the training in boosting and homogenizing employee performance assessments.

Table 4-7 Paired-Sample t-Test for Departmental Annual Evaluation Before and After Training (n=547)

Paired Variable	Mean	Standard Deviation	Mean Difference	t-Value	p-Value
Two-Year Post- Training Annual Average	73.550	26.125	16.217	13.488***	.000
Three-Year Pre- Training Annual Average	57.333	34.065			

***p<.001

The statistical data in Table 4-7 strongly indicates that the training significantly improved departmental annual evaluation scores, t(547) = 13.488, p < .000. The average post-training evaluation score showed a significant increase (mean = 16.217), reflecting enhanced professionalism and strong job performance among participants, which led to higher departmental evaluation scores. This demonstrates that implementing the practical training program for safety supervisors has a significant effect on improving participants' departmental evaluation scores.

4.5 Comprehensive Discussion

Kirkpatrick's four-level evaluation model was used to assess the behavioral and outcome levels of the

training. The results of this study show that the practical safety training course significantly improved trainees' certification bonuses, audit irregularities, and annual performance appraisals, supporting research hypotheses H1-1 through H1-3. The departmental annual evaluation scores results also showed significant improvement, supporting hypothesis H2-1.

In summary, the practical safety training course had a significant effect on enhancing both the professional skills and work performance of the trainees, at both the behavioral and outcome levels.

5. CONCLUSION AND RECOMMENDATIONS

This study aims to evaluate the effectiveness of the practical safety training program for safety supervisors in the petrochemical industry. Using ten years of data from Company A, a scientific statistical analysis was conducted on participating employees to gain a deeper understanding of performance changes before and after training. Based on the research findings, this chapter provides specific conclusions and recommendations for course design, instruction, and corporate decision-making.

5.1 Key Findings

Through data analysis, the following key findings were derived:

A. Behavioral Performance:

- a. **Certification Bonus:** The results indicate a significant increase in the two-year post-training annual average certification bonus score, $t(547) = 6.563$, $p = .000$. Through a combination of theoretical and practical instruction, participants gained a deeper understanding of safety regulations and obtained more safety-related professional certifications.
- b. **Audit Irregularities:** The number of audit irregularities significantly decreased within two years post-training, $t(547) = -5.360$, $p = .000$. Improved professional skills among participants after training contributed to fewer irregularities during internal and external audits.
- c. **Annual Performance Appraisal:** The two-year post-training annual average performance appraisal score showed a significant increase, $t(547) = 12.110$, $p = .000$. Enhanced professional abilities and work performance among participants led to better annual performance appraisals compared to the pre-training period.

B. Outcome Performance:

The results showed a significant increase in departmental annual evaluation scores two years after training, $t(547) = 13.488$, $p = .000$. The improvement in trainees' professionalism and work performance contributed to a notable improvement in departmental evaluation scores.

5.2 Conclusion

In summary, the practical training program for safety supervisors had a significant positive impact on both behavioral and outcome levels. The program notably increased certification bonuses, reduced audit irregularities, and improved annual performance appraisals as well as departmental annual evaluation scores.

5.3 Recommendations

- A. **Course Design and Teaching Improvement:** Course design should focus on individualized needs, with an emphasis on enhancing interactive learning and hands-on instruction to encourage active participation and improve learning outcomes. This approach can also be applied to other process and maintenance training programs to further enhance training effectiveness.
- B. **Further Research:** It is recommended that future research incorporate variables such as age, years of service, gender, experience, and expertise for a more in-depth analysis. This would allow for exploring differences in learning outcomes among participants with diverse backgrounds, providing more specific recommendations for course improvement.

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