Development of Training Curricula to Improve Engineers' Learning Capacity in Manufacturing Facilities Using the Production Support System Based on DAPOA

Chamnan Ratsame, King Mongkut's University of Technology Thonburi, Thailand
Pakpoom Chansri, King Mongkut's University of Technology Thonburi, Thailand

The Asian Conference on Education 2024
Official Conference Proceedings

Abstract

To provide training experience for engineers working in industrial plants, this research developed and evaluated a training model for industrial production support systems using the DAPOA learning framework. The five steps of the DAPOA project learning model were used to organize teaching and learning for the academic year 2023–2024. These steps are topic identification, analysis, planning and design, implementation, and evaluation. The study of the production support system combined theoretical and practical teaching approaches. The study used a sample group of 20 plant engineers who expressed interest in participating in the experiment. We examined classroom and workplace skills and assessed the trainees' abilities. The results showed that the DAPOA project learning framework was moderate-to-highly appropriate. Following the training, the establishment's air compressor system engineers demonstrated significantly higher knowledge and practical abilities. This training course design also worked because the DAPOA learning model worked well. It gave an average result (E1/E2) of 80.45/83.95 percent, which showed that engineers were better at analyzing data in industrial compressed air systems. Although some parts of the training steps for energy analysis of compressed air systems were deemed appropriate by experts, all assessments were carried out by experts about energy use standards for industrial production support equipment and the standards were found to be appropriate. The practical training manual of the sample group had the highest satisfaction ($\bar{x}$=4.45) according to the evaluation results.

Keywords: DAPOA, Competency, Engineer, Production Support

Introduction

At present, the industrial sector is facing technological changes. Developing energy management systems (El-Fawair et al., 2023) in the production process is a crucial factor that can enhance efficiency and reduce costs. One such system is the compressed air system, a high-energy system that plays a significant role in industrial production. Without effective management, the compressed air system will affect the organization's competitiveness. However, international guidelines such as ISO 50001 (Chaves et al., 2020) have certified appropriate energy management, emphasizing efficient and sustainable energy use. Past research has revealed that lecture-based learning (LBL) (Dutta et al., 2022) offers benefits such as time and resource savings in teaching and learning but also suffers from a deficiency in skill training. The demonstration learning model, also known as Simulation-Based Learning (SBL) (Pratumsuwan et al., 2020), suffers from a lack of continuous training in evaluation skills and process improvement, and it cannot cover all situations that may arise in real-world scenarios. The project-based learning model (PBL) (Honglin et al., 2022) enhances problem-solving skills in real-world scenarios, such as fostering analytical thinking, planning, and teamwork. However, the evaluation process may be unclear as the results may not demonstrate complete success. This research presents a learning model that combines process-based learning and the DAPOA (Determination, Analysis, Plan, Operate, Assess) process. Process-based learning focuses on learning that emphasizes clear process understanding and systematic steps to follow, while DAPOA process steps enhance skills in planning, evaluation, and continuous process improvement. Therefore, combining these two approaches will enhance important skills in energy management processes in industrial engineers.

Overview of Research

Process-Based Learning and Training Processes in DAPOA Model

Process-Based Learning (PBL) (Heng et al., 2024; Li et al., 2024) is a theory of learning that emphasizes learning through actual practice, making it suitable for training on air compressors. We will teach learners through activities that align with their learning content, enabling them to solve problems in real-world scenarios. This training will help increase experience and confidence in deep, sustainable learning. It also helps as a guideline for energy use in production, especially using air compressor systems according to energy management standards that focus on improving energy efficiency. This research will introduce a learning management model based on the DAPOA principle, a training model for knowledge creation that prioritizes the practical application of scientific processes and problem-solving techniques, as illustrated in Figure 1. The model is divided into five steps as follows:

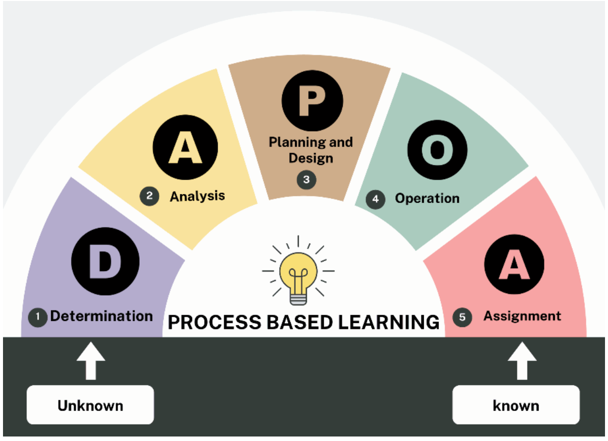


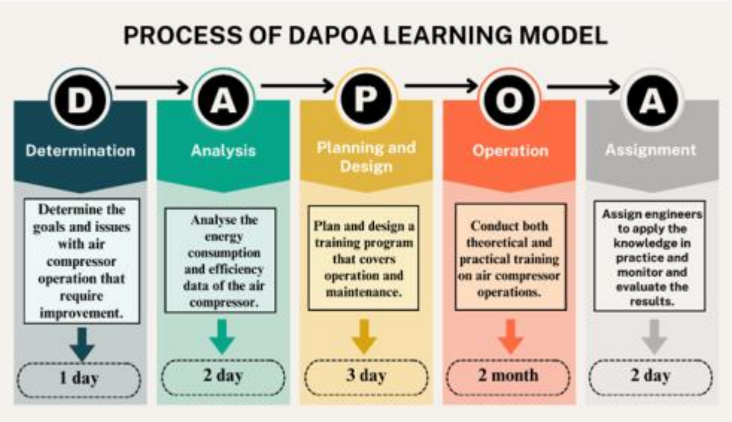
Figure 1: The DAPOA Process-Based Learning Model

Determination: The process of determining the goals and objectives of the training content.
Analysis: The process of analyzing relevant theoretical data to help trainees gain a deeper understanding of the problem.
Planning and Design: This refers to strategizing enhancements by outlining specific steps and methods for implementation in the laboratory to compile an analysis of evaluation criteria that impact the compressed air system (Thabet et al., 2020; Kasprzyk et al., 2023).
Operation: The process of implementing the plan that requires continuous improvement and monitoring of progress in each of the trainee's establishments.
Assignment: The process of evaluating the results and evaluating the learning efficiency to summarize the results of improving the production process.

Learning and Teaching Processes

Research Design.

This research is experimental. Production engineers comprise the research population, who are in charge of using air compressor systems in industrial plants. The sample group was selected by purposive sampling from 20 establishments. Figure 2 illustrates the training of air compressor systems using the DAPOA principle in the process-based learning model. The target data will be related to the efficiency of air compressor use and the skills of the trainees will be collected and analyzed both before and after the training.



Determine the goals and issues with air compressor operation that require improvement.

Analyse the energy consumption and efficiency data of the air compressor.

Plan and design a training program that covers operation and maintenance.

Conduct both theoretical and practical training on air compressor operations.

Assign engineers to apply the knowledge in practice and monitor and evaluate the results.

Figure 2: The Process-Based Learning of DAPOA Learning Model

Research Procedures.

Determination Stage (D): The initial process begins with defining the training objectives and goals, which is a crucial step that directly affects the success of air compressor training. Consistency with workplace problems and needs and the desired expectations for trained engineers are crucial for practical training. Examples include,

- Establishing training objectives involves determining the knowledge and understanding that trainees must possess and their ability to analyze and evaluate after training. Examples of training objectives in this regard include increasing knowledge and understanding of air compressors. Developing skills in using compressed air systems. Reducing energy consumption in compressed air systems.
- The objectives of theoretical training are what is desired to be achieved after the training is completed. These objectives can be used as indicators of the success of training and the development of the trainees' potential. The objectives of this training will focus on increasing the efficiency of air compressor usage and reducing energy costs in the production process in the organization.
- Setting key performance indicators (KPIs) is important in evaluating training results that can be used in this case, including trainee satisfaction level.

Analysis Stage (A): Data analysis is an important step after defining training objectives and goals, as shown in Fig. 3. This step collects data related to compressed air system usage, along with additional data from the determination step, to analyze the efficiency of compressed air system usage.

Figure 3: Analysis Process

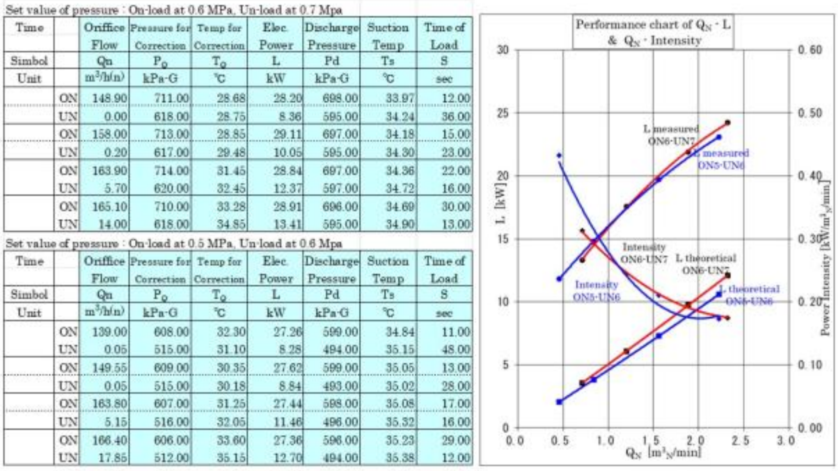
- Data Collection: Analysis of the data obtained can be used to evaluate the efficiency of air compressor usage and plan training, such as Energy Efficiency Analysis. Analyzing the energy use of air compressors is an important step in finding ways to reduce energy consumption and improve efficiency.
- Conclusion: The presentation of the conclusions obtained from analyzing each issue will be important information for designing training content consistent with specific training problems and needs.
- Evaluation: This analysis will lead to the design of training content that is precise and responsive to the problems encountered in the air compressor operation process, to the evaluation of learners' progress after training, to the training achievement.

Planning and Design Stage (P): Two days of practical theoretical training on air compressor systems. Figure 4 shows the training program on appropriate and sustainable electric energy-saving techniques of air compressors. After completing the contents according to the specified objectives, an experiment worksheet will be organized.

Figure 4: Planning and Design Process

Operation Stage (O): In this phase, learners will participate in the training according to the plan, focusing on learning through actual practice in a safe environment. In the practical phase, learners will try to use the actual air compressor with an expert instructor to guide and answer questions. The practical training will commence with a simulated air compressor room demonstration and actual practice. The design of the content and preparation of training documents are based on the data obtained from the previous analysis step. Divide into groups of 5 people and test the operation of the 22 KW electric air compressor to identify the variables that influence the energy consumption of the air compressor in the upcoming section.

- Testing of flow rate adjustment using valve of air compressor system.



Set value of pressure : On-load at 0.6 MPa, Un-load at 0.7 Mpa

Time		Oriffice Flow	Pressure for Correction	Temp for Correction	Elec. Power	Discharge Pressure	Suction Temp	Time of Load
Simbol		Qn	P_Q	T_Q	L	Pd	Ts	S
Unit		$m^3/h(n)$	kPa-G	℃	kW	kPa-G	℃	sec
	ON	148.90	711.00	28.68	28.20	698.00	33.97	12.00
	UN	0.00	618.00	28.75	8.36	595.00	34.24	36.00
	ON	158.00	713.00	28.85	29.11	697.00	34.18	15.00
	UN	0.20	617.00	29.48	10.05	595.00	34.30	23.00
	ON	163.90	714.00	31.45	28.84	697.00	34.36	22.00
	UN	5.70	620.00	32.45	12.37	597.00	34.72	16.00
	ON	165.10	710.00	33.28	28.91	696.00	34.69	30.00
	UN	14.00	618.00	34.85	13.41	595.00	34.90	13.00

Set value of pressure : On-load at 0.5 MPa, Un-load at 0.6 Mpa

Time		Oriffice Flow	Pressure for Correction	Temp for Correction	Elec. Power	Discharge Pressure	Suction Temp	Time of Load
Simbol		Qn	P_Q	T_Q	L	Pd	Ts	S
Unit		$m^3/h(n)$	kPa-G	℃	kW	kPa-G	℃	sec
	ON	139.00	608.00	32.30	27.26	599.00	34.84	11.00
	UN	0.05	515.00	31.10	8.28	494.00	35.15	48.00
	ON	149.55	609.00	30.35	27.62	599.00	35.05	13.00
	UN	0.05	515.00	30.18	8.84	493.00	35.02	28.00
	ON	163.80	607.00	31.25	27.44	598.00	35.08	17.00
	UN	5.15	516.00	32.05	11.46	496.00	35.32	16.00
	ON	166.40	606.00	33.60	27.36	596.00	35.23	29.00
	UN	17.85	512.00	35.15	12.70	494.00	35.38	12.00

Figure 5: Summary of Data That Illustrates the Correlation Between Flow Rate and Electrical Power During the Test

Figure 5 summarizes the experimental results. Higher compressed air flow rates due to valve adjustments result in higher load and lower drain conditions. For example, the experimental log shows that at a flow rate of 1.461 m3N/min, we measured 29.110 kW of electrical power in the load phase and 10.058 kW in the working phase, with a working period of 15 seconds and a stopping period of 23 seconds. Therefore, the average electrical power of the compressor in this operating condition is 17.57 kW.

Table 1: Results From the Graph Showing the Relationship Between Average Electrical Power and Compressed Air Flow Rate

Flow rate		**Electrical power**		**Period**		**Power Average**	**Saving percentage**	
m^3N/min	%	Load (KW)	Unload (KW)	Load (Sec)	Unload (Sec)	(KW)	(KW)	%
0.925	35.83	29.20	8.36	12.00	36.00	13.57	10.65	43.97
1.461	56.57	29.12	10.04	15.00	23.00	17.57	6.64	27.45
2.142	82.98	28.68	12.96	22.00	16.00	22.06	2.15	8.91
2.581	100.00	28.90	13.42	30.00	13.00	24.22	-	-

From Table 1, the higher the air flow rate, the higher the average power. Therefore, the correct use of an air compressor must consider the appropriate amount of air demand. The experiment results show that adjusting the flow rate to 1.461 m3N/min can reduce the valve to 56.579%, resulting in an average power reduction of 6.64 KW, or 27.45% of the power required to open the valve at 100%.

- Pressure loss testing in various pipe sizes of compressed air systems

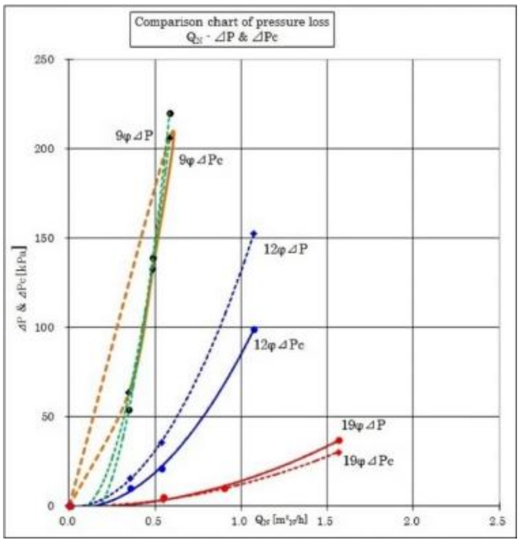


Figure 6: Summary of Pressure Loss Data in Various Pipe Sizes of Compressed Air System

A summary of the pressure loss test results in various pipe sizes of the air compressor system is shown in Figure 6. When considering the test result recording table and the obtained graph, it was found that when the pipe is small, the pressure loss in the pipe is more significant. At the same time, if the airflow rate is greater, the pressure in the pipe is more significant. Therefore, selecting the appropriate pipe size is another way to save energy. Usually, the pipe size is selected from the velocity of compressed air flowing in the pipe, which will be between 25 and 40 meters per second.

- Air leakage loss test of the compressed air system.

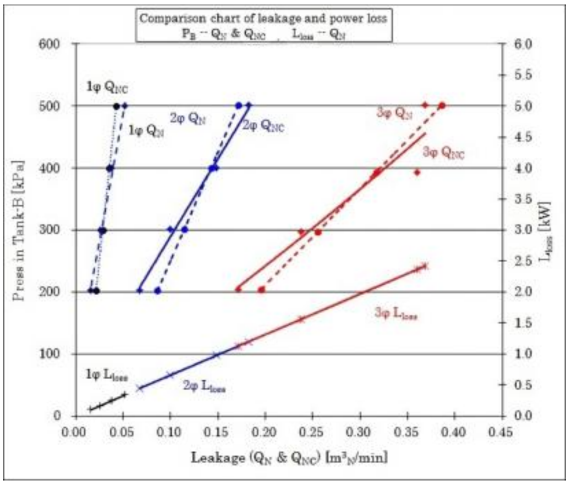
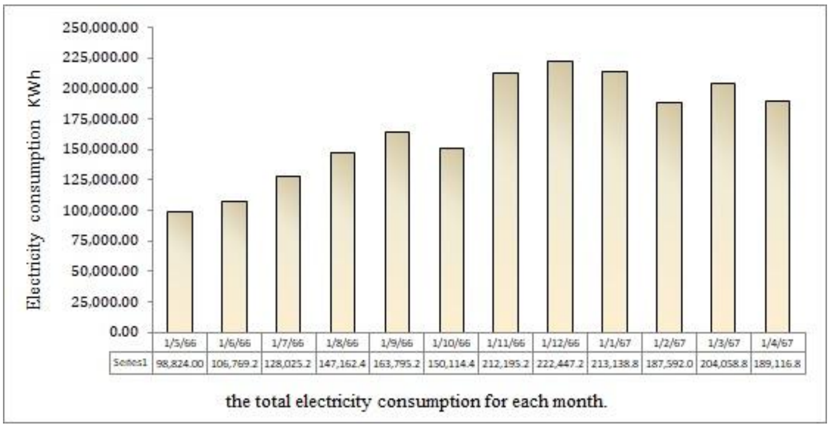


Figure 7: Data Showing Air Leakage Loss Test Results of the Compressed Air System

From the test results in Figure 7. The test of air leakage loss of the compressed air system, when considering the graph comparing the loss of different size holes with the lost electrical power to be a straight line.

Assessment Stage (A): In order to measure the success of the training program in this research, the trainees were required to return to their work on the energy use of air compressors project. They were instructed to use the PDCA (Xu, 2020) energy management planning principle to evaluate their performance, enabling them to plan, operate, inspect, and improve systematically. The following case study summarizes the operation steps.

- The planning process involves gathering data on electricity usage for product production.



	1/5/66	1/6/66	1/7/66	1/8/66	1/9/66	1/10/66	1/11/66	1/12/66	1/1/67	1/2/67	1/3/67	1/4/67
Series1	98,824.00	106,769.2	128,025.2	147,162.4	163,795.2	150,114.4	212,195.2	222,447.2	213,138.8	187,592.0	204,058.8	189,116.8

Figure 8: Graph Showing Electricity Consumption Data and Production Before Operation

Figure 8. It was found that the average electricity usage per month was 168,603.27 kilowatt hours., with 39,502 products produced. The average electricity usage trend per shot was 4.25 KWh. This data will be used for analysis to create a regression model equation to predict the amount of electricity usage appropriate for the production process. Then, another experiment was conducted to collect data according to the planned data under the regression equation that was compared with the data before and after the improvement of the project, along with a summary of the results of the operation.

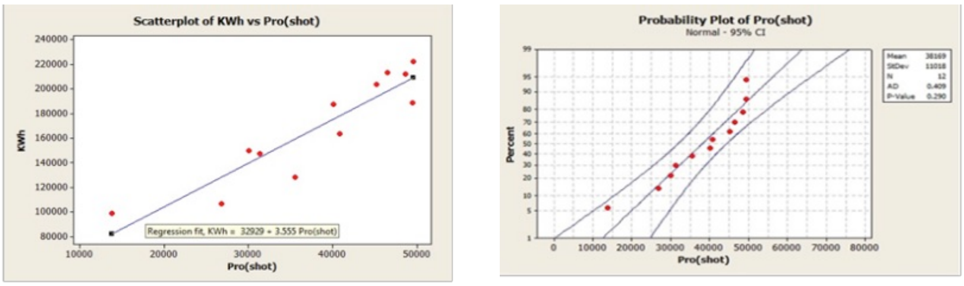


Figure 9: Scatter Plot Between Electrical Energy and Monthly Output

From the analysis of the prediction equation between electrical energy and monthly production, shown in Figure 9, it was found to be equal to KWh=3.55 Pro(shot)+32929, where R-Sq(adj)=82.9%, meaning that the production volume can predict the electrical energy consumption by 82.9%. The remaining 17.10% is influenced by other factors, with a P-value of 0.00. For the form of the normal probability plot of a residual graph.

- Methods for collecting data on air compressor systems from preliminary assessments.

Figure 10: Measurement of Usage Before the Improvement

Table 2: Data Obtained from the Measurements

Data obtained from preliminary measurements to calculate Free Air Delivery (FAD comp)	
Compressed air storage tank size V_{tank} (m^3)	12
Time taken to compress air into the tank from minimum to maximum pressure (sec)	153.04
Maximum test pressure (bar_g)	8.00
Minimum test pressure (bar_g)	7.00
Total size of pipe before distribution to use V_{pipe} (m^3)	0.97
Absolute atmospheric pressure, P_{atm} (bar)	1.013
Electrical power (KW)	39.98

- The results of the obtained data are analyzed to improve energy efficiency.

The calculation of free air delivery efficiency (FAD comp) (Mei et al., 2020) of an air compressor uses the following calculation equation:

$$FADcomp = \frac{(P_{2g}-P_{1g})(V_{Pipe}-V_{tank})}{(P_{atm})(t)} \tag{1}$$

Summary of the results from Table 2. The efficiency value (FAD comp) of the air compressor from the calculation of equation 1. is equal to 5.020 m3/min or 0.084 m3/sec.

Therefore, the specific energy consumption value when the machine is under load (KW on Load/FAD) is equal to 7.966 KW/m^3/min. When comparing the performance and efficiency and electrical energy in air compression according to the standard 1/sec/KW at a value of 0.45, it was found that the efficiency of the machine is equal to 94%.

- Analysis and calculation of energy leakage rate of a compressed air system.

Data from monitoring and data collection can be used to calculate the compressed air leakage rate of the system using Equation 2.

$$\mathrm{FAD_{leak}} = \left(\frac{\mathrm{t_{onload}}}{\mathrm{t_{onload}} + \mathrm{t_{unload}}}\right) \mathrm{FAD_{comp}} \tag{2}$$

The results from the test were summarized and calculated according to the theory. When the compressor was working (onload) 171.30 sec, stopped working (unload) 193.60 sec, the efficiency (FAD comp) of the air compressor was 0.074 m^3/sec. The leakage of compressed air was found to be 0.035 m^3/sec, which is a leakage rate of 12.50% or the electric energy of the air compressor that was reduced by 24,336 KWh/year.

- Analysis and calculation of pressure reduction

Data from the monitoring and data collection can be used to calculate measures to reduce the pressure of the compressed air system using Equation 3.

$$\mathrm{KW_{th}} = 1.205\left[\mathrm{T_1} - \mathrm{T_{1adj}}\right]_1 \left[\left(\frac{\mathrm{P_2}}{\mathrm{P_1}}\right)^{0.286} - 1\right] (\mathrm{FAD})_{\mathrm{com}} \tag{3}$$

Summarize the results from the test and calculate according to the theory. When setting the operation of the air compressor, starting from reducing the level of the low value from the original 7 bar down to 6 bar and reducing the maximum value of 8 bar down to 7 bar, the absolute temperature value is 308 Kelvin and the efficiency value of the air compressor (FAD) comp is 0.091 m3/sec. The calculation will find that the electrical energy value before reducing the pressure is equal to 29.49 KW. After reducing the pressure, the electrical energy used will be equal to 27.39 KW, which is an energy reduction rate of 7.12%, or the electrical energy of the air compressor that is reduced will be equal to 15,120 KWh/year.

- Analysis and calculation of suction temperature of air compressor.

$$\Delta \mathrm{W_{isen}} = \frac{ik\mathrm{R_w T_1} - \mathrm{T_2}}{k-1}\left[\left(\frac{\mathrm{P_2}}{\mathrm{P_1}}\right)^{\left(\frac{k-1}{i*k}\right)} - 1\right]$$

(4)

$$\mathrm{KW} = \Delta \mathrm{W_{isen}} * \mathrm{Da_{(kJ/kg)}} * \mathrm{FAD_{(l/sec)}} * \%\mathrm{L_{DU}}$$

(5)

where,

D_a = Densities of Air, 1.225×10^{-3} kg/liter
L_{DU} = Fraction of Onload status
i = Stage Compressor
K = Isentropic of Air Constant

R_w = Gas Contant at T_1
T_1 = Air inlet Temperature Before Improving
T_2 = Air inlet Temperature After Improving

Summarize the results from the test and calculate from equation 4,5. When reducing the working temperature of the air compressor from the original 40 degrees Celsius and adjusting to reduce the air intake to 35 degrees Celsius, the low-pressure value is 7 bar and the highest value is 8 bar, and the efficiency of the air compressor (FAD) is 0.091 m^3/sec. It can be seen that the electrical energy value before reducing the pressure is equal to 29.49 KW. After adjusting to reduce the suction temperature into the air compressor by 5 degrees Celsius, the electrical energy used will be equal to 28.63 KW, which is an energy reduction rate of 2.91% or the electrical energy of the air compressor that is reduced equal to 6,192 KWh /year.

- Summary of operating results

This assessment of the project trainers was done by collecting data on compressed air systems to determine the performance and efficiency of the air compressors. Three measures were implemented, and it was found that the total electrical energy usage could be reduced by 45,648 KWh/year. When comparing with the data before the implementation of the preliminary data for 12 months, it was found that the electrical energy cost was reduced by 2.25%, with the average electrical energy usage trend per product value being 4.17 KWh/shot.

Research Results

In summary, The IOC (Index of Item-Objective Congruence) evaluation results are based on the 5-level evaluation principle of Lickel (Guo et al.,2023) of the air compressor training content, both in theory and practice, with 5 experts from higher education institutes and the Ministry of Energy as content experts. The criteria for considering the content consistency value are +1 means appropriate, -1 means inappropriate. The summary of the evaluation results of the consistency value is between 0.67 and 1.00, with values higher than 0.50 considered to pass all criteria, with an average value of 4.30 and a standard deviation of 0.55. The evaluation of the quality of satisfaction uses a 5-level evaluation scale: very satisfied, satisfied, moderately satisfied, slightly dissatisfied, and extremely dissatisfied. Overall, the experts evaluated the quality at a good level, with the evaluation results as shown in Table 3.

Table 3: Results of Evaluation of Air Compressor Training Content in Theory and Practice

Topics of theoretical training content	$\bar{X}$	**S.D.**	**Opinion Level**
Working principle of an air compressed system	4.50	0.65	Excellent
Air compressed system efficiency	4.62	0.51	Excellent
Safety of air compressor systems	4.23	0.52	**good**
System stability and reliability	4.30	0.47	**good**
Maintenance and care of air compressor systems	4.12	0.58	**good**
Environmental impacts	3.98	0.56	**good**
Responding to user needs	4.30	0.45	**good**
Average	**4.29**	**0.53**	**good**
Training content topics in practical section	$\bar{X}$	**S.D.**	**Opinion Level**
Study of air compressed systems and components	4.40	0.43	**good**
Pre-testing system check	4.42	0.57	**good**
Setting parameters for testing	4.51	0.52	Excellent
Performance testing	4.53	0.62	Excellent
Air compressor safety testing	3.95	0.63	**good**
Continuous operation and durability testing	3.92	0.66	**good**
Recording test results and analyzing test summaries	4.43	0.55	**good**
Average	**4.31**	**0.57**	**good**
Average Total	4.30	0.55	good

Results of the evaluation of learners' satisfaction with the developed learning model. The results of the evaluation of learners' satisfaction with the teaching management using the developed DAPOA process-based learning model revealed that the trainees were overall satisfied at a satisfactory level (mean 4.13 and S.D. 0.23). They agreed that the developed learning model focused on learners, promoted diverse learning activities, and clearly integrated many disciplines. In addition, the designed learning media and activities could develop learners to learn by themselves, leading to practical application in the air compressor system. The results of the research are shown in Table 4.

Table 4: Results of the Evaluation of Participants' Satisfaction in Learning Using the DAPOA Process as a Base

Evaluation list	$\bar{X}$	**S.D.**	**Quality level**
DAPOA Model Learning Model.	**3.93**	**0.27**	Satisfied
1. learning format supports the teaching curriculum.	3.87	0.35	Satisfied
2. learning process that focuses on developing the trainees.	4.30	0.41	Very Satisfied
3. Learning processes that are related and continuous.	4.15	0.46	Satisfied
4. Teaching and learning activities are appropriate and sufficient.	3.93	0.88	Satisfied
5. learning format promotes learning appropriately.	3.40	0.51	Satisfied
Teaching and learning activities are organized in a process-based manner.	**4.00**	**0.41**	Satisfied
1. Activities are consistent with the DAPOA Model learning model.	4.35	0.52	Very Satisfied
2. The specified activities can be performed at the specified time.	3.98	0.62	Satisfied
3. Learning activities are diverse and integrated.	4.23	0.52	Satisfied
4. The developed learning activities help the learners to learn by themselves.	3.85	0.56	Satisfied
5. Learners interact/work/do activities together.	3.60	0.51	Satisfied
Process-based teaching management	**4.12**	**0.30**	Satisfied
1. The duration of the event is appropriate.	4.18	0.50	Satisfied
2. Promotion of knowledge competence	3.78	0.51	Satisfied
3. Promotion of practical skills	4.35	0.51	Very Satisfied
4. Promotion of creative thinking skills	4.10	0.57	Satisfied
5. Can manage teaching and learning appropriately.	4.21	0.72	Very Satisfied
Measurement and Evaluation	**4.45**	**0.24**	Very Satisfied
1. Can assess both knowledge, abilities, and skills.	4.28	0.41	Very Satisfied
2. The measurement and evaluation methods are consistent with the learning model.	4.26	0.57	Very Satisfied
3.You can use it to evaluate each step because it is multipurpose.	4.67	0.49	Very Satisfied
4. Evaluation criteria are clear and appropriate.	4.58	0.50	Very Satisfied
5.The measurement method can be used to collect learning data according to the actual training content.	4.56	0.51	Very Satisfied
Overall satisfaction in all aspects.	**4.13**	**0.23**	Satisfied

Efficiency analysis results of the DAPOA process-based training model The evaluation of the effectiveness of the developed learning model used in the compressed air training during the training in the created laboratory and after the training of the project in the workplace of the trainees found that the average value of the process (E1) was 80.45 percent, and after the training of the project in the workplace, the average value of the outcome (E2) was 83.95 percent, which is consistent with and meets the specified standard criteria of 80/80. The results of the research are shown in Table 5.

Table 5: Results of Analysis of the Effectiveness of Training Using a Process-Based Model

Knowledge and skill tests	**Score obtained**		**Average Percentage**	**Efficiency of learning models**
	Full score	**Average score**		
Laboratory training (Process or E1)	100	80.45	80.45	80.45 / 83.95
Project training in the workplace (Result or E2)	100	83.95	83.95	

Conclusion

The design of the training program on air compressor system learning for engineers working in industrial plants using the developed DAPOA process-based learning model, which consists of 5 steps: 1. Determination 2. Analysis 3. Planning and Design 4. Operation and 5. Assessment found that the learning model emphasizes the participants learning and creating quality knowledge by themselves that can be used to manage the use of air compressors for higher efficiency appropriately. When tested with a sample group of trainees, it was found that the training program method, including knowledge in the content after the practical training, showed that the learning achievement increased, especially in the operation and development of the air compressor system. From the follow-up of the work performance after learning according to the process-based learning model, it was found that the trainees were very satisfied with the training program because they could use their knowledge and work skills to improve the efficiency of the air compressor.

Acknowledgements

I would like to express my deepest gratitude to the Electrical Education Program, Faculty of Industrial Education and Technology, for their valuable advice and encouragement throughout this research. I would also like to thank King Mongkut's University of Technology Thonburi (KMUTT) for their support and participation. I would like to express my special thanks to my colleagues for their useful suggestions and to my family and friends for their unwavering support. Your joint efforts made this work possible, and I am deeply grateful.

References

Chaves, J. D., Gallego, M. I., Aguilar, D., González, P. F., Vidal, M. J. R., & Quispe, E. C. (2020). Estimation of the Energy Saving Potentials in Foundry Industries Based on ISO 50001, *in IEEE Latin America Transactions*, vol. 18, no. 12, pp. 2155-2165.

Dutta, N. S., & Arnold, C. B. (2022). Illuminating the Role of Classmates in Reducing the Participation Gender Gap in Lecture-Based Engineering Classes, *in IEEE Transactions on Education*, vol. 65, no. 4, pp. 584-591.

El-Fawair, B., Al-Aubidy, K. M., & Al-Khawaldeh, M. A. (2023). Energy Management in Microgrids with Renewable Energy Sources and Energy Storage System, 20th International Multi-Conference on Systems, Signals & Devices (SSD), Mahdia, Tunisia, pp. 801-806.

Guo, M., & Peng, F. (2023). A Survey of the Logistics Service Quality Level for Courier Enterprises based on Likert Scale using the R Language, *2023 IEEE 3rd International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA)*, Chongqing, China, pp. 1586-1589.

Heng, C. H., Toyoura, M., Leow, C. S., & Nishizaki, H. (2024). Analysis of Classroom Processes Based on Deep Learning with Video and Audio Features, *in IEEE Access*, vol. 12, pp. 110705-110712.

Honglin, L., & Yifan, N. (2022). The Construction of Project-Based Learning Model Based on Design Thinking, *2022 4th International Conference on Computer Science and Technologies in Education (CSTE)*, Xi'an, China, pp. 173-177.

Kasprzyk, K., & Gałuszka, A. (2023). Energy savings possibilities gained from neural network application in compressed air supervisory control systems, *2023 27th International Conference on Methods and Models in Automation and Robotics (MMAR)*, Międzyzdroje, Poland, pp. 279-285.

Li, F., Li, H., & Wu, C. (2024). Gaussian Process Based Learning Model Predictive Control With Application to USV, *in IEEE Transactions on Industrial Electronics*, vol. 71, no. 12, pp. 16388-16397.

Mei, J., Lu, Z., Hu, J., & Fan, Y. (2020). Energy-Efficient Optimal Guaranteed Cost Intermittent-Switch Control of a Direct Expansion Air Conditioning System, *in IEEE/CAA Journal of Automatica Sinica*, vol. 8, no. 11, pp. 1852-1866.

Pratumsuwan, P., Seuyphinnid, K., & Tonggoed, T. (2020). Simulation-based Learning in Fluid Power Engineering through Line Chat Application, *2022 International Conference on Engineering and Emerging Technologies (ICEET)*, Kuala Lumpur, Malaysia, pp. 1-5.

Thabet, M., Sanders, D., Becerra, V., Tewkesbury, G., Haddad, M., & Barker, T. (2020). Intelligent Energy Management of Compressed Air Systems, *2020 IEEE 10th International Conference on Intelligent Systems (IS)*, Varna, Bulgaria, pp. 153-158.

Xu, B. (2020). Performance Management Model of Public Expenditure Based on PDCA Cycle Theory, *2020 International Conference on E-Commerce and Internet Technology (ECIT)*, Zhangjiajie, China, pp. 216-221.

Contact email: Chamnan.rat@kmutt.ac.th