CHAPTER 5
Results and Analysis

5.1 Chapter overview

This chapter presents the results and analysis of the case studies described in Chapter 4. This aim of this chapter is to find evidence which supports the research hypotheses. The first section of the chapter presents the facts which confirm that the framework can be used to identify the ability of switchgear maintenance personnel better than traditional method. The second section shows that the proposed framework and knowledge engineering methodology are appropriate methods to develop the visual inspection knowledge game scenario. In this research, the framework is used to structure the game story meaning the game developer can increase and improve the contents of the game story any time. The third section presents the results which show that the knowledge game can motivate and enhance the employee performance better than current HRD interventions.

5.2 Case Study 1 : Capability Level of PEA N3 Substation Maintenance Personnel

5.2.1 Testing Result

After the robustness test of the capability classification model discussed in Chapter 3, this model was tested with the predefined case study. This evaluation was performed by self and supervisory assessment method. In this evaluation process, the placement of maintenance personnel was conducted by interviewing with the already developed questions which are presented in the appendix. The difficulty level of the placement questions will go higher depending on the answers each trainee gives. The supervisor of personnel was asked to join in the interview process. The results of testing were plotted onto the radar diagram of classification model to identify the skill and knowledge gap. Figure 5.1 presents the competency evaluation of new technician. This new technician has worked as a substation maintenance worker for less than 1 year.

Figure 5.2 shows the result of the competency evaluation of the technician who has worked for 4 years in the substation maintenance job. Figure 5.3 shows the competencies of senior technician who has worked for 7 years in this task. Finally, the Figure 5.4 shows the classification model of supervisor. He has been responsible for substation maintenance more than 7 years.

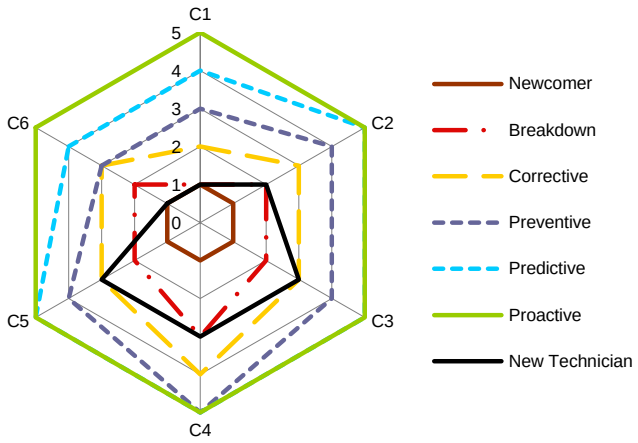

Figure 5.1 Competency Profile of PEA N3 New Technician

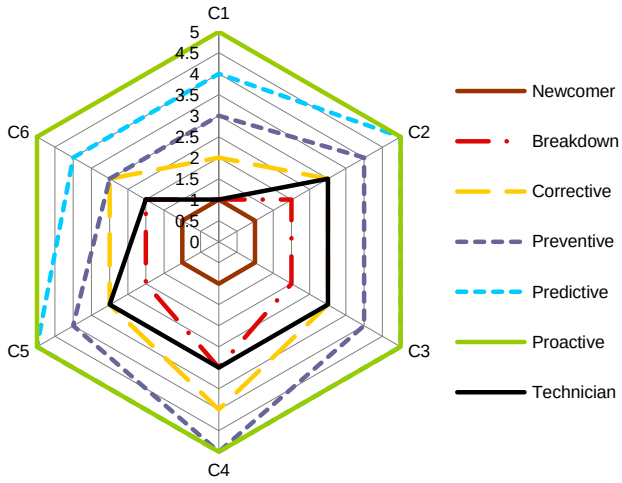

Figure 5.2 Competency Profile of PEA N3 Technician

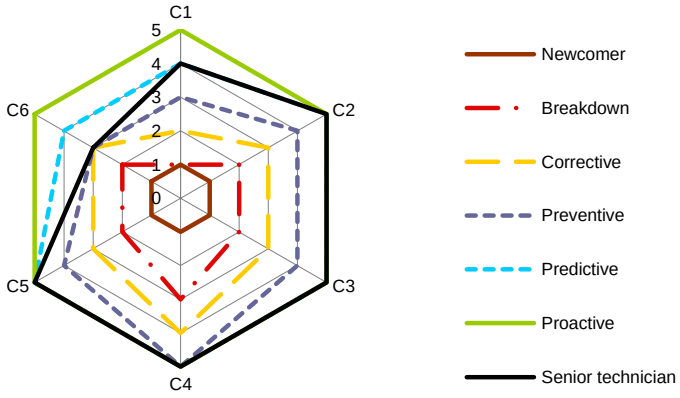

Figure 5.3 Competency Profile of PEA N3 Senior Technician

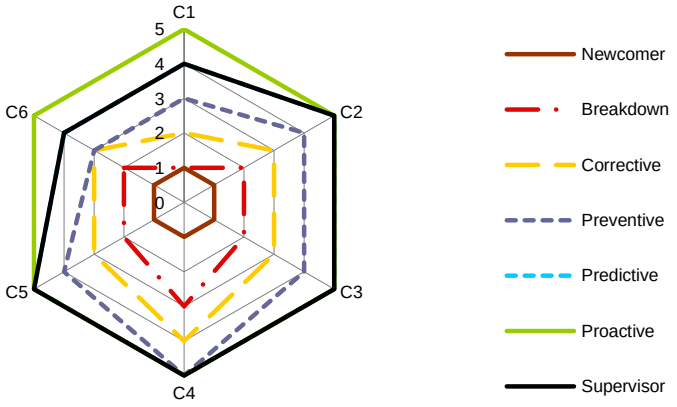

Figure 5.4 Competency Profile of PEA N3 Supervisor

After finishing the evaluation, the chief supervisor of the interviewees was asked to analyze and verify the results of competency evaluation. During this process, the chief supervisor was interviewed about the human errors of both personnel, which occurred in individual maintenance operation. Based on the interview, the chief indicated the mistakes of their subordinates.

According to the observation at work, it was found that the technician and new technicians often make mistakes in measuring instrument usage and parameter recording. The chief supervisor stated these mistakes as follow:

"The duty of technician and new technician during measuring process is to connect the measuring instrument in order to test the circuit breaker. They have to connect the instrument clamp to the measuring position on circuit breaker. Then they recorded the measuring data. The mistake occurred when they connect the instrument clamp to the circuit breaker terminator. They connected the instrument clamp at wrong position. Therefore, the data was lower than true value. When the supervisor checked the connection he found that the points of connection were wrong. Therefore, he revised the connection, and then the record data was correct."

The evidence of this mistake in decision is shown in the report. This mistake illustrates that the new technician and technicians lack the skills to use the instrument. The lack of this knowledge can also be confirmed in the knowledge and skill assessment diagram shown in Figure 5.1 and 5.2.

For the senior technician observation, it was found that the senior technician made a mistake in the decision when evaluating the condition of the circuit breaker. This can be elaborated as follows:

"The duty after finishing the maintenance job of Mr.X (senior technician) is to evaluate the condition of the circuit breaker. The evaluation is performed by monitoring the insulation resistance value. Normally, the PEA standard defines that the condition of normal vacuum circuit breaker must be over one Giga Ohm. This mistake in decision occurred because the insulation resistance value of the circuit breaker A is greater than one Giga Ohm. Therefore, he decided not to replace the circuit breaker A. However, when his chief supervisor observed the data, he found that the measuring value was quite close to one Gaga Ohm, while the measuring values of another circuit breakers under the same condition at the same substation, were greater than three hundred Giga Ohm. Therefore, the data showed that there were some problems occurring with circuit

breaker A. Then, the supervisor had to make the decision to replace the circuit breaker A with the new one."

The evidence of this mistake in decision is shown in the substation maintenance report. This mistake in decision of senior technician illustrates that he lacks the skill to observe the data and compare it with another circuit breaker or historical data rather than simply following the standard. The lack of this knowledge can also be confirmed in the knowledge and skill assessment diagram shown in Figure 5.3. It shows that the senior technician lacks the assessment competency.

After the capability level of each employee is verified, the proper knowledge and skill according to individual capability level and maturity development aspect are selected. In this case, Figure 5.1 and 5.2 indicate that the technician and new technician lacked competency in planning, measuring, and assessment analysis. Therefore, they have to develop the knowledge and skills listed in Table 5.1 and 5.2 consequently. Figure 5.3 shows that the senior technician competency is almost close to predictive level. However, he lacks the monitoring competency in manage level. Therefore, the list of knowledge and skill in Table 5.3 are selected to enhance his capability.

Table 5.1 Knowledge and Skill Requirement for New Technician

Competency	Knowledge and Skill
Planning	(1) Planning process (2) Maintenance process
Coordination	(1) Concerning unit (2) SAP (3) Inventory system
Maintenance Operation	-
Measuring	(1) Availability check of measuring instrument (2) Instrument usability and testing procedure
Equipment Correction	-
Assessment analysis	(1) Concerning parameter (2) Norm value of equipment

Table 5.2 Knowledge and Skill Requirement for Technician

Competency	Knowledge and Skill
Planning	(1) Planning process (2) Maintenance process
Coordination	-
Maintenance Operation	-
Measuring	(1) Availability check of measuring instrument (2) Instrument usability and testing procedure
Equipment Correction	-
Assessment analysis	(1) Norm value of equipment

Table 5.3 Knowledge and Skill Requirement for Senior Technician

Competency	Knowledge and Skill
Planning	-
Coordination	-
Maintenance Operation	-
Measuring	-
Equipment Correction	-
Assessment analysis	(1) Data observation (2) Knowledge to compare the present value with historical case

With the knowledge and skill developments analyzed and listed in Table 5.1, 5.2 and 5.3, the line manager and HRD department can set up the training and development method to fill the competency gap of each substation maintenance personnel efficiently.

5.2.2 Analysis and Discussion

The results of the evaluation have shown that the classification model can be used effectively to identify the capability level of the personnel. Moreover, unlike

conventional competency methodology, this framework also identifies the set of knowledge and skill for further development according to maturity level. HRD department can also utilize this information to develop training and development program suitable for each maintenance personnel. The utilization and benefits of the proposed framework are quite different from the current PEA competency model. The comparison between the current competency model and the capability classification model proposed in this paper can be seen in Table 5.4.

Table 5.4 Comparison Between Current Competency Model Development and Proposed Classification Model

Topic	Current Competency Model	Capability Classification Model
Objective	To support various HR activities	Focus on training and development
Competency Type	- Core competency - Functional competency include managerial and technical competency	- Technical competency
Data Gathering Method	- Descriptive meeting - Focus group - Benchmarking	- Subject matter expert structural interview with CommonKADS
Competency Mapping Method	- Supervisory assessment survey - Benchmarking	- Competency analysis table - CMM - Supervisory assessment
Competency Model of Substation Maintenance Section	- Protective device in distribution system - Inventory system - Electrical equipment installation and maintenance - Analytical skill - Coordination skill - Attention to details	- Planning - Coordination - Maintenance operation - Measuring - Equipment correction - Assessment analysis

Table 5.4 Comparison Between Current Competency Model Development and Proposed Classification Model (Continued)

Topic	Current Competency Model	Capability Classification Model
Proficiency Level	Five patterns Level1: Beginner Level2: Apply Level3: Supervise Level4: Master Level5: Strategic	Capability maturity model Level1: Initial Level2: Repeat Level3: Define Level4: Manage Level5: Optimize

Table 5.4 shows that the proposed framework "capability classification model" emphasizes more on training and development aspects. It focuses on how to develop the specific skill of specific jobs. Therefore, the capability classification model contains the competencies that are related to the maintenance engineering perspective. This is in contrary to the current competency framework which focuses on the development of the competency model to support various HR functions. It contains both managerial and technical competency. The technical competencies as part of the proposed framework are set up based on knowledge and experience of subject matter experts with the utilization of KE method. It means that the personnel performance is evaluated by comparing to the maintenance expert, or in other words, how close it is to the performance of the experts. Moreover, the results of the case study have shown that the proposed framework is the proper practical method to classify the knowledge and skill level of the individual personnel. With this maintenance maturity model, the specific knowledge and skill can be defined to train the personnel in each level. Then, organization can use the list of knowledge and skill for the proper future development program to enhance the individual personnel performance. Therefore, the H1 hypothesis is justified. Furthermore, the proposed framework needs the effort of subject matter experts only in data gathering phase and validation step. This implies that the proposed framework consumes less of the experts' time than current PEA competency model method.

5.3 Case Study 2: 22 kV Switchgear Maintenance Training Course

5.3.1 Testing Result

This case study was done by using the first prototypes of game which are developed based on knowledge of PEA N3 experts. This prototype was tested by maintenance expert of PEA C1. The scenario which used in this case study is the game scenario in corrective level. The testing result is shown as Table 5.5.

Table 5.5 Results of Game Prototype V.1 Testing by PEA C1 Expert

Activity	Score		
	Expect	Pre-test	Post-test
Activity No.1	100%	0%	100%
Activity No.2	80%	80%	80%
Activity No.3	80%	60%	100%
Activity No.4	83%	100%	100%
Activity No.5	100%	100%	100%
Activity No.6	100%	100%	100%
Activity No.7	100%	100%	100%
Activity No.8	100%	100%	100%
Activity No.9	83%	100%	100%

According to the results in the table, it was found that the player cannot do the activity No.1. This activity is the planning scenario. In this matter, the player was interviewed to analyze this mention. The player stated that the planning process of PEA C1 is not the same as process in the game scenario. Therefore, the knowledge capture was done to get the knowledge of maintenance planning process of PEA C1. The knowledge capture process is done by proposed development framework which presents in Chapter 3. This development scenario needs to interview the expert only data gathering step. The experts need not to devote a significant amount of his time in this process.

After the knowledge was captured, it is used to analyze following the proposed framework. Then the new scenario was developed based on maintenance capability

classification model. This new scenario is the planning scenario of the corrective level. After that the planning scenario of first prototype is replaced by a new scenario. Finally, the second prototype was used to test with technician of PEA C1. The result of testing is shown as Table 5.6.

Table 5.6 Results of Game Prototype V.2 Testing by PEA C1 Technician

Activity	Score		
	Expect	Pre-test	Post-test
Activity No.1	100%	33%	100%
Activity No.2	80%	40%	80%
Activity No.3	80%	20%	80%
Activity No.4	83%	83%	100%
Activity No.5	100%	100%	100%
Activity No.6	100%	100%	100%
Activity No.7	100%	100%	100%
Activity No.8	100%	100%	100%
Activity No.9	83%	100%	100%

5.3.2 Analysis and Discussion

The results of case study shows that the proposed game structure allowed the game developer in order to increase or improve the contents without the need to correct the entire content of the game. The scenario development framework and knowledge engineering can be applied to capture the knowledge and experience of PEA C1 expert. From the case study, the planning scenario is the only difference between the prototype version 1 and 2. Therefore, the scenario development framework and knowledge engineering are applied for capturing the knowledge of PEA C1 expert. Then the experiment shows that the trainee who is the technician of PEA C1 is familiar with game content in prototype version 2. He can play the game from the beginning to the end without confusion. This can be implied that the contents of game developed by using proposed structure can develop only the specific part without the need to change the contents of game. Furthermore, the proposed framework needs the effort of subject

matter experts only in data gathering phase and validation step. This implies that the proposed framework consumes less of the experts' time. This matter can justify the hypotheses H2 and H3.

5.4 Case Study 3 : Personnel Development in 22 kV Switchgear Maintenance

5.4.1 Testing Result

The testing process was done to investigate the knowledge, behavior, and opinion of trainees. The process includes 3 sub-processes; knowledge testing, behavior change observation and game efficiency survey. The result of 3 tests can be shown individual in this section.

5.4.1.1 Knowledge Testing

The knowledge testing process measured the increased knowledge after the trainee played the game. This testing process stars by asking trainees to do the pre-test in the placement scenario. After that the trainees learned the maintenance knowledge by playing the game scenario. Finally, the trainees did the post-test. Both scores and time taken to finish the pre-test and post-test were compared to investigate the increased in knowledge of individual. All recording are shown in Tables 5.7 - 5.12.

Table 5.7 Knowledge Testing Results of Trainee No.1 (New Technician)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	90	90	26	100%	62%	100%
Activity No.2	75	75	41	100%	60%	100%
Activity No.3	75	58	34	83%	33%	83%
Activity No.4	60	47	13	100%	83%	100%

Table 5.8 Knowledge Testing Results of Trainee No.2 (New Engineer)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	90	90	22	100%	41%	100%
Activity No.2	75	75	31	100%	20%	100%
Activity No.3	75	75	35	83%	33%	100%
Activity No.4	60	60	14	100%	33%	100%

Table 5.9 Knowledge Testing Results of Trainee No.3 (Technician)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	60	60	47	100%	0%	88%
Activity No.2	40	40	36	80%	60%	100%
Activity No.3	40	40	24	80%	40%	100%
Activity No.4	90	90	90	83%	33%	83%
Activity No.5	60	52	27	100%	100%	100%
Activity No.6	60	48	32	100%	100%	100%
Activity No.7	30	19	16	100%	66%	100%
Activity No.8	30	14	12	100%	100%	100%
Activity No.9	30	30	18	83%	33%	83%

Table 5.10 Knowledge Testing Results of Trainee No.4 (Technician)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	60	60	45	100%	0%	78%
Activity No.2	40	40	34	80%	80%	100%
Activity No.3	40	40	27	80%	0%	80%
Activity No.4	90	78	71	83%	50%	100%
Activity No.5	60	33	29	100%	100%	100%
Activity No.6	60	35	27	100%	100%	100%

Table 5.10 Knowledge Testing Results of Trainee No.4 (Technician) (Continued)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.7	30	16	14	100%	100%	100%
Activity No.8	30	15	12	100%	100%	100%
Activity No.9	30	28	19	83%	33%	100%

Table 5.11 Knowledge Testing Results of Trainee No.5 (Technician)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	60	60	45	100%	33%	100%
Activity No.2	40	40	25	80%	40%	80%
Activity No.3	40	40	22	80%	20%	80%
Activity No.4	90	86	46	83%	83%	100%
Activity No.5	60	51	23	100%	100%	100%
Activity No.6	60	21	24	100%	100%	100%
Activity No.7	30	11	12	100%	100%	100%
Activity No.8	30	20	16	100%	100%	100%
Activity No.9	30	28	18	83%	100%	100%

Table 5.12 Knowledge Testing Results of Trainee No.6 (Engineer)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.1	60	60	44	100%	0%	100%
Activity No.2	40	40	20	80%	80%	80%
Activity No.3	40	29	30	80%	60%	100%
Activity No.4	90	84	49	83%	100%	100%
Activity No.5	60	42	30	100%	100%	100%
Activity No.6	60	29	25	100%	100%	100%
Activity No.7	30	14	12	100%	100%	100%

Table 5.12 Knowledge Testing Results of Trainee No.6 (Engineer) (Continued)

Activity	Time (Second)			Score		
	Time limit	Pre-test	Post-test	Expect	Pre-test	Post-test
Activity No.8	30	27	14	100%	100%	100%
Activity No.9	30	25	11	83%	100%	100%

5.4.1.2 Behavior Change Observation

The behavior change observation was carried out during the trainees play the game. The trainees' behavior was observed and recorded by video recorder. These recorded videos were used to analyze and investigate the behavior change after learning in the game. This section lists the change of individual behavior after learning in the game:

Trainee No.1:

- More accurate decision
- More certain decision
- Reduced time for decision

Trainee No.2:

- More accurate decision
- Remembered the equipment
- Familiarity with maintenance jargon
- More confident in making decisions
- Familiarity with the game
- Reduced time for decision

Trainee No 3:

- More confident in making decisions
- Familiarity with the game
- Enthusiasm for learning
- Reduced time for decision

Trainee No.4:

- More accurate decision
- Enthusiasm for learning
- Familiarity with game

Trainee No.5:

- Make decision with more confidence
- Understand contents of the game
- Familiarity with the game
- Familiarity with the game environment
- Reduced time for decision

Trainee No.6:

- Understand contents of the game
- Familiarity with the game
- Familiarity with the game environment
- Reduced time for decision

5.4.1.3 Game efficiency survey

The game efficiency survey was done after trainees finished the game playing. The players were asked to make the opinion survey to analyze the game's effectiveness according to Prensky's theory and Flow theory. The survey form is divided into 2 parts. The first part is the prototype evaluation. The research proposes to apply the EGameFlowfor this part (Fu, Su, and Yu, 2008). The second part is the prototype evaluation compare with traditional development methods. The questionnaire is shown in the appendix. Table 5.13 presents the summary results of the prototype evaluation. The Table 5.14 presents the prototype evaluation compared with traditional development methods.

Table 5.13 The Summary Results of Prototype Evaluation

Factor	Trainee1	Trainee2	Trainee3	Trainee4	Trainee5	Trainee6	Average
1. Concentration	4.83	4.17	4.17	4.33	4.5	4.5	4.42
2. Goal Clarity	5.00	5.00	4.50	4.25	4.50	5.00	4.71
3. Feedback	5.00	5.00	4.00	4.00	4.80	4.80	4.60
4. Challenge	4.40	4.00	4.40	3.80	4.00	4.00	4.10
5. Autonomy	5.00	4.00	4.50	3.00	3.50	4.50	4.08
6. Immersion	4.71	3.71	4.71	4.29	4.29	4.00	4.29
7. Knowledge Improvement	5.00	4.20	5.00	4.20	4.20	4.60	4.53

Table 5.14 The Prototype Evaluation in Comparison to Traditional Development Methods

Factor	Trainee1	Trainee2	Trainee3	Trainee4	Trainee5	Trainee6	Average
Concentration	4.00	4.00	5.00	4.00	4.00	3.00	4.00
Goal Clarity	3.00	4.00	4.00	4.00	4.00	4.00	3.83
Feedback	5.00	4.00	5.00	4.00	5.00	4.00	4.50
Challenge	4.00	4.00	4.00	4.00	5.00	4.00	4.17
Immersion	5.00	4.00	5.00	5.00	5.00	5.00	4.83
Knowledge Improvement	5.00	4.00	4.00	5.00	4.00	3.00	4.17

5.4.2 Analysis and Discussion

Analysis of Trainee No.1

Trainee no.1 is the new technician who was given responsibility of substation maintenance task not over than 1 year. The placement test and pre-test show that his score is lower than the expected score. His ability is at the new comer level of maintenance classification model. From the test, it was found that after he played the game, he can make better decisions more than he did in the pre-test. He received better

score and took less time than he took in the pre-test. For the behavior change observation, it was found that after learning by game, he can make better decisions with certainty and accuracy.

Analysis of Trainee No.2

Trainee no.2 is the new engineer who has never carried out a substation maintenance task before. The placement test and pre-test show that his level is the new comer level. From the knowledge test, it was found that after the trainee learned with the game, she received a better score and took less time than for the pre-test. For the behavior change observation, it was found that after learning by game, she can understand the maintenance jargons.

Analysis of Trainee No.3

Trainee no.3 is the technician. He has 5 years experience in switchgear maintenance. From the pre-test score, it was found that he had prior knowledge and understanding in preventive operation. He knows how to clean and lubricate the circuit breaker. He also knows well about the measuring instrument. However, by learning in the game, he can reduce the time that he used for decision-making. The behavior observation shows that the learning in game can increase the confidence of decision.

Analysis of Trainee No.4

Trainee no.4 is the technician who has been responsible for substation maintenance for 1 year. He has adequate knowledge in maintenance operation process and measuring instrument usability because of he graduated with an electrical engineering degree. Moreover, he had worked in a maintenance position a manufacture company before he joined PEA. However, learning in the game gave the benefit by helping him make better decisions. His decisions are more accurate after he played the game.

Analysis of Trainee No.5

Trainee no.5 is the technician who has good experience in maintenance task. The testing results showed that the knowledge and ability of trainee no.5 is higher than the game level. However, he cannot do the planning activity because he has never done

the planning process before. Therefore, the score of activity 1 is quite low. However, after he played the game, he received a higher score. From this we can deduct that playing the game supported the trainee to better understand the planning process.

Analysis of Trainee No.6

Trainee no.6 is a senior engineer. He has a good knowledge in maintenance process. However, the results showed that he couldn't do activity 1, the planning scenario. From the interview conducted after finishing the game, it was discovered that he couldn't do this activity because he was not familiar with the process and the equipment. The contents of the planning scenario developed based on the knowledge of PEA N3 experts were different from PEA C1 process. However, after he played the game, he became familiar with the game environment and made the right decisions. Therefore, the game helped him understand new knowledge which resulted in higher score in the post-test.

Analysis of game efficiency survey

The first part of the game efficiency survey results showed that the game prototype is suitable for enhancing the maintenance skill and knowledge. All of the trainees agreed that they concentrated in the game. The game provides a clear objective and goal of learning. It also provided the feedback for reporting the learning progress to the player. The contents of the game are appropriate and challenging for them. However, trainee no.4 and 5 for instance stated that the scenario was quite easy for them. Finally, all of them agreed that this game is suitable for improving their knowledge.

The second part of the survey presents the efficacy of the game compared to the traditional method. The trainees agreed that the game is better than traditional method in all aspects. However, some players stated that some traditional methods such as on-the-job training can also provide similar environments to the game.

Discussion

The testing results showed that the whole trainees can do the post-test better than pre-test. The post-test scores are significantly higher than the pre-test scores.

Moreover, the time taken for the trainees to make decisions in the post-tests were less than it took in the pre-tests. This matter means that the contents of game scenario can provide the information, knowledge and appropriate learning method to the trainees. Moreover, the result of the game efficiency survey shows that the trainees had been motivated to learn in this game. They were also satisfied with the game level and expressed that the game is a more appropriate method than traditional development methods. In this matter, the H4 and H5 are proved.

5.5 Chapter Summary

This chapter presented the results and analysis of the case studies. These results were analyzed to find out the evidence to prove the research hypotheses shown in Chapter 1. These results showed that the research framework is the proper method for enhancing the performance of switchgear maintenance staff. This framework can be used to develop the game-based knowledge management which provides the appropriate learning motivation, learning environment, learning contents, and learning pattern. It can be used to identify the capability of the players. This framework can be used to classify the capability of the maintenance staff which is better than the traditional method. Moreover, it provides the benefit to the game developer in order to increase the game contents anytime. However, the traditional training and development are also necessary method for trainees in order to enhance some knowledge such as new technology and new tool. Therefore, PEA should provide both knowledge game and traditional method for efficiency enhancing the maintenance staff performance.