CHAPTER 4 RESULTS

This chapter presents the results from this study. Results are presented in three sections. The first contains results that experts' establish a model of knowledge-based expert system for car faulty diagnosis that provides guidance. The reasoning engine was illustrated an integrated diagnosis system based on the KBESCFD model from experience and existing knowledge. The second section contains results that perceptions and transferable a model of knowledge-based expert system for car faulty diagnosis in the diverse of concept maps with human expertise reasoning.

Researchers have collected the "expert-concept constructed concept map" with judgmentally, and discussion on automotive troubleshooting tasks. The third section presents results that the implementation of the KBESCFD through computer-assisted concept mapping as training strategy are differentiated scores in the study.

4.1 Phase I: Establishing of a knowledge-based expert system for car faulty diagnosis model

The summarized questions were raised by 11 training managers from 8 well-known the car automobile companies in Thailand who were involved in curriculum development/training program development. The results revealed that:

What are the key characteristics of KBESCFD?

In the order to develop the key characteristics of KBESCFD, participants were proposed variety model follow the context of company. Researcher can be explored the effective model through the triangulation method was referred to validate the data and feedback with a quality assessment form from all participants completely. KBESCFD had the frequency of exceptional that consensus by all participants.

"KBESCFD must convey several attributes of the problem, including an extensive of the case context: descriptions of the performance environment, the practitioners and their relationships with each other, and the problem" (Jonassen, 2004, p. 53).

Five major categories emerged in the open coding process. These categories were drawn directly from the data. It was named: (1) explore possible causes, (2) fault symptoms diagnosis, (3) hypothesis generation, (4) test/simulation, and (5) solutions. In open coding, properties of the categories are also examined as well as dimensions that categories are properly grouped together, are saturated. The results revealed that as shown in Table 4.1.

Table 4.1 Open coding of KBESCFD model

Category	Properties	Dimensionalized examples	
Explore possible causes	Construct problem space Pre-Inspection Drive testing	Cause-behavioral sequence relations Assumption of the system's output or system components Confirm for ordering and fixing and repair	Customer complain Experiential and Working memory Decision support system
Fault symptoms diagnosis	Knowledge acquisition Prior experience Diagnose fault(s) Generate and verify solutions	Knowledge states Knowledge presentation Knowledge representation Reasoning	Capacities Performance
Hypothesis generation	Experienced Procedures Categories problems	Prior knowledge Experience knowledge Previous experience	Cognitive processing Procedural knowledge Working memory
Test/simulation	Recognizing symptoms Faulty components	Malfunction skills Metacognitve reasoning	Mental problem space KBESCFD
Solutions	Procedures Perform suggested Specific competences Special competences	System, Subsystem, Device, Component Problem-solving skills Artificial Intelligent systems	System analysis Decision making skills Service manual KBESCFD

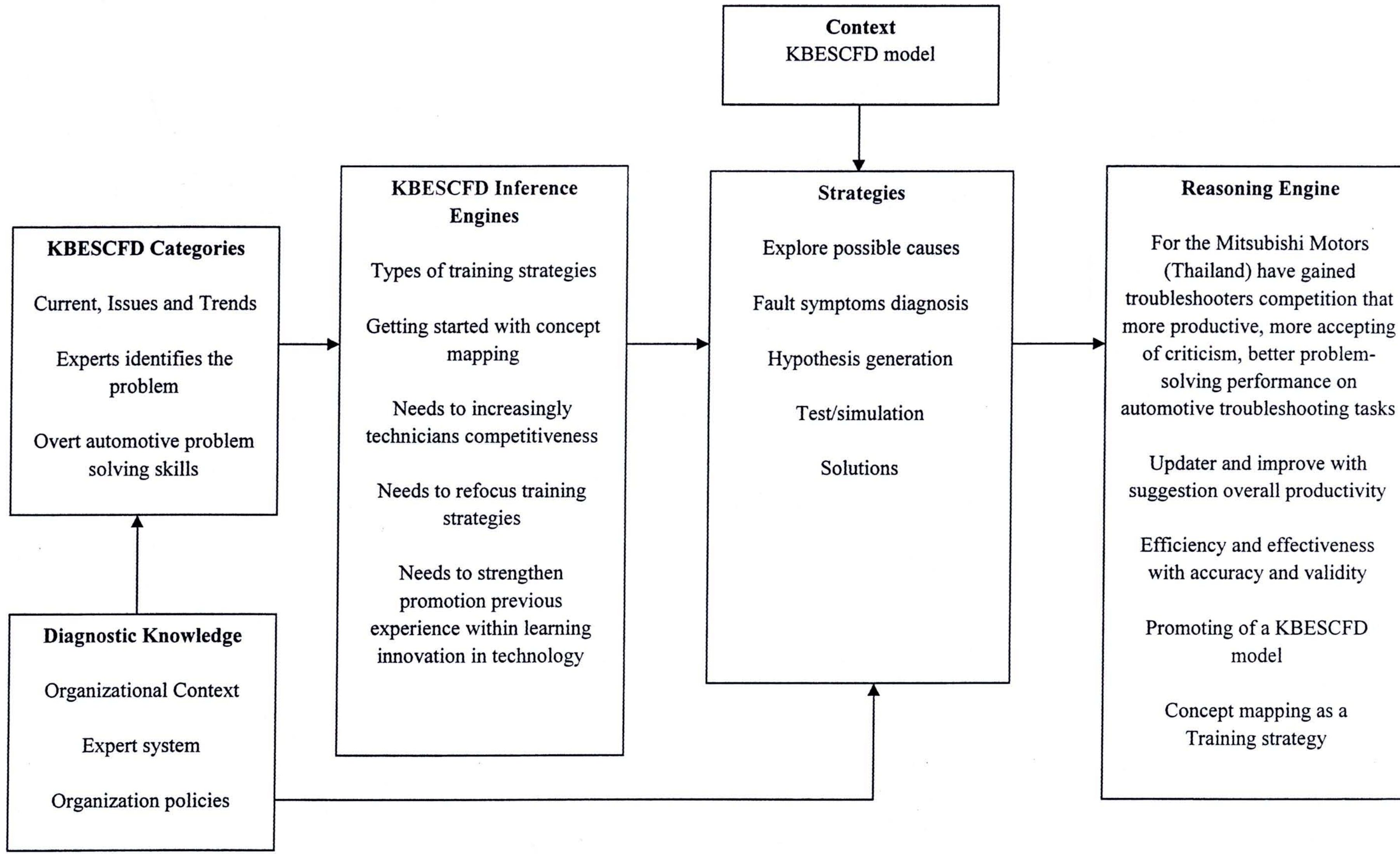

Figure 4.1 Axial and selective coding: Paradigm of a KBESCFD model

From Table 4.2 axial coding involves identifying single categories as the central phenomenon and exploring its relationship to the other categories. The central phenomenon is identified as well as the conditions that give rise to it, the context in which it is embedded, the action or interactional strategies, by which it is handled, and the consequences of those strategies (Strauss & Corbin: 1990, 1998). In the results, axial coding a paradigm model is created integrating selective coding which visually portrays the relationship among the categories. Figure 4.1 represents the integrating axial and selective coding paradigm model.

An integrated diagnosis system based on the KBESCFD model can be proposed in Figure 4.2. Researchers presented a model have been contributed expert system. The KBESCFD model is formed through the integration of several functions in Table 4.1 that had five categories constitute of the problem-solving process of automotive service technicians in the context of Thailand. The activity occurring in each step is expressed by an observable behavior in a format similar to a behavioral objective as shown in Figure 4.2.

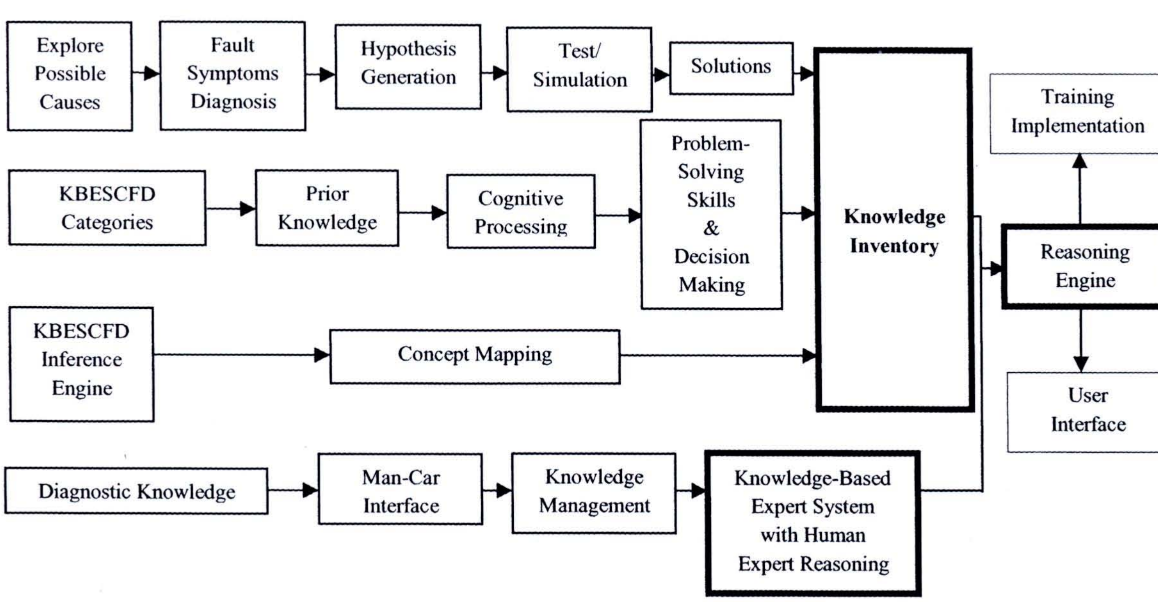

Figure 4.2 A knowledge-based expert system model for car faulty diagnosis

In the KBESCFD model, knowledge inventory, knowledge-based expert system and reasoning engine are the three major functional modules. The implementation of these modules is discussed.

4.2 Phase II: Experts' perceptions and transferable a KBESCFD model in the diverse of concept maps with human expertise reasoning

Researchers employed the KBESCFD for transferring a rule-based scoring system designed to capture on problem-solving skills for Mitsubishi automotive service technicians. The pattern is spoke (one or two central concepts with links to at least five other nodes), chain (at least 5 nodes, which typically represent stages in the problem-solving process), and net (an overall integrated pattern with subsets of connected links). Overall reliability of concept map sorting was .91 agreement and reliabilities of individual categories was .94 agreement.

The assessment concept maps were analyzed by quantitative and qualitative approach. The quantitative analysis included a regarding of the concept maps by using revised criteria and a comparison with previous experiences. The qualitative analysis included a synthesis of crucial factors by Kinchin and Hay (2000). This task was innovative in its use of concept maps to illustrate their knowledge structure of automotive problem-solving. Such use of concept maps includes: 1) a *task* that allows the expertise's to provide previous experiences, 2) a *format* for the response and 3) a *scoring system* to evaluate the concept map (Kinchin & Hay, 2000).

4.2.1Expert-concept constructed concept map results

The six maps were passed by experts' rater, and consisted of 1) Diesel engine faulty diagnosis; 2) Multi-point injection engine (MPI) faulty diagnosis; 3) Common-rail diesel direct injection system (CRD) faulty diagnosis; 4) Steering system faulty diagnosis; 5) Manual transmission faulty diagnosis; and 6) Automatic transmission faulty diagnosis. As whole as, experts' rater accepted as shown in Table 4.3

Table 4.2 Research-criteria (RC) assessment rubric for the concept maps task

Research Criteria	Description	Weighting	Interpretation
RC 1	*Content* – inclusion of the problem occurs (concepts)	45%	Excellent

Table 4.2 Research-criteria (RC) assessment rubric for the concept maps task (Continued)

Research Criteria	Description	Weighting	Interpretation
RC 2	*Hierarchy* – concepts organized from initial skills towards the advanced skills of problem occurs	27%	Appropriate
RC 3	*Links/Node* – computed average number of links per node	36%	Appropriate
RC 4	*Branching* – count of nodes with greater than 2 outgoing links	12%	Appropriate
RC 5	*Merging* – count of nodes with greater than 1 ingoing links	30%	Excellent
RC 6	*Linking Words* – quality of linking words	45%	Excellent

4.2.2 Expert-concept constructed concept map scores and ranking

Table 4.3 Concept map scores and ranking based on the research criteria

Problem presentation (Cases)	Research criteria scores Frequency	Ranking
Multi-point injection engine	6	1
Common-rail diesel direct injection system	6	1
Diesel engine	5	2
Manual transmission system	5	2
Automatic transmission system	4	3
Suspension system	4	3
Brake system	4	4
Air conditioning system	4	5
Steering system	4	5
Vibration system	3	6

In Table 4.3, concept mapping the expertise constructs that indicates interrelationships among concepts that represent meaning in specific domains. The expertise arranges concepts as perceived the KBESCFD model, (perceived regularities designated by a label,) hierarchically. Concepts progress from most general at the central to most specific at the right and left. Concepts are linked for meaning by linking words such as: to form, have, are, like, produces, including, resulting in, acts on. Cross linkages indicate relationships among concepts. As an instructional technique, concept mapping involves students in their own learning, encourages to link prior knowledge with new information, deals with curriculum content, encourages problem solving and planning, and enables them to see where they need to fill in gaps in their knowledge.

For the expertise's, the *concept maps task* required construction of "a comprehensive topic to include all listed concepts hierarchical organized into an interconnected network, including meaningful descriptions of the relationships of the relationship between connecting nodes and illustrative examples for the more specific concepts, preferably towards the bottom." The *format* (type) of concept maps required was *construct-map (concepts provided)*. The *scoring system* was an *assessment rule-based scoring system* as shown in Table 4.3, adopted from Novak's Scoring Protocol (Novak & Gowin, 1984).

As an assessment technique, concept mapping is integrated with instruction to continue progress in automotive training. Concept mapping can measure practitioner progress and achievement, and promote self-reflection by providing feedback on training progress. The trainer can assess concept maps by examining them for number of concepts, quality of linkages, appropriateness of the hierarchical organization, and richness of cross linkages. During a concept mapping session, depending on their preferences, expertise can work individually, to create a map using paper with the computer using programs IHMC Cmaps Tools version 4.18).

A concept map is often based on a summary of a subsection of a unit. Expertises wrote each concept of the "spoket" on a separate paper. They arrange the Cmaps programming starting at the top of a large sheet of paper with the most general concept branching in a hierarchical order towards the problem occurs. Expertise's frequently move the Cmaps programming around several times before linking-lines and words.

Often expertise's inspected their maps and recognizes that they can organize the concepts better. They rearrange the concepts, add additional ones and draw more cross linkages. The expertise's then examine the maps of other students. They can rearrange their maps any way they would like and discuss differences with participants.

As a facilitator, the researchers can circulate during map construction and encourage students by asking questions such as:

Can you see a relationship between these concepts?
What else do you know about this concept that would be relevant to the map?
How could you rearrange this map to make it easier to read or interpret?

Expertise's reported that the KBESCFD model discussions them validity and reliability information better. They rate it as an enjoyable and worthwhile activity. Concept maps help to dispel previous experience by revealing them. Concept mapping also meets the needs of visual and kinesthetic technicians.

4.3 Phase III: Determine the effectiveness of the knowledge-based expert system for car faulty diagnosis

This phase reports the results of the cognitive tests and surveys, which were analyzed as measures of Training achievement and satisfaction. The session will analyze the data collected during the study around twothemes:

1. Comparing training achievement on knowledge acquisition and concept mapping in both groups
2. Find out the training satisfaction

The analysis of the data collected for the KBESCFD model study involved comparing the differences between computer-assisted concept mapping group (CA-CM) and service manual concept mapping group (SM-CM) to see whether or not there was a significant difference between experimental and control groups. Statistical computations were conducted using Statistical Package for Social Science (SPSS). To compare the mean scores of these two groups' independent samples t-tests were employed. The t-test is one of the most commonly used techniques for testing a hypothesis on the basis of a difference between sample means (Creswell, 2008). The t-test determines a probability that two samples are the same with respect to the variable tested.

Throughout the study, the default 0.05 level of significance was used. Null hypotheses were rejected whenever the *p* values obtained in the calculations were less than 0.05. The SPSS program was used for conducting statistical analyses, manipulating data, and generating tables and graphs that summarize data. Description and comparison of profiles of troubleshooters as in many quasi-experimental studies, intact groups were used; that is the memberships of the experimental and comparison groups were naturally assembled through their class sections. For test purposes, the two groups should ideally be as alike and interchangeable as possible. However, since quasi-experiments do not call for equivalence of the two groups under consideration, no attempts were made to intentionally match or equalize their characteristics, or to minimize the differences existing between them.

4.3.1 Comparing training achievement on knowledge acquisition

The comparison of the learning outcomes on knowledge acquisition of both CA-CM and SM-CM learning strategies was made through using the pre-test and post-test scores. Performance of the two groups in the 50-question pre-test showed that while the mean of the CA-CM scores was 35.531, the mean of the SM-CM scores was 33.437, the correlations of pre-test scores on knowledge acquisition was $r = -.063$ that had high negative relationship and the t-test independent on the pre-test scores of CA-CM and SM-CM groups indicated that $t = 1.451$ there was no significant difference as shown in Table 4.4.

Table 4.4 Comparison of pre-test scores of technicians on knowledge acquisition

Group	N	Mean	SD	t	*df*	Sig (2 tailed)
CA-CM	32	35.531	5.999	1.451	31	.157
SM-CM	32	33.437	5.173			

*Note. *p < .05 (Independent sample t-test)*

	N	Correlation	Sig.
Post & Pre CA-CM	32	-.063	.733

Performance of the two groups in the 50-question post-test showed that while the mean of the CA-CM scores was 38.375, the mean of the SM-CM scores was 37.781, the results of correlations of post-test scores on knowledge acquisition was $r = -.068$ that had high negative relationship and the t-test independent on the post-test scores of the CA-CM and SM-CM groups indicated that $t = .479$ there was no significant difference as shown in Table 4.5.

Table 4.5 Comparison of post-test scores of technicians on knowledge acquisition

Group	N	Mean	SD	t	*df*	Sig (2 tailed)
CA-CM	32	38.375	5.091	.479	31	.635
SM-CM	32	37.781	4.484			

Note. **p < .05 (Independent sample t-test)*

	N	Correlation	Sig.
Post & Pre CA-CM	32	-.068	.710

4.3.2 Comparing pre-test and post-test results on knowledge acquisition

Considering the differences between pre-test and post-test results for both groups using paired-sample t-test procedure, there was a significant difference between pre-test and post-test results for the CA-CM group as shown in Table 4.6. The mean of pre-test and post-test scores was 35.531 and 38.375, and the results of correlations of post-test scores on knowledge acquisition was $r = .886$ that had high positive relationship. The t-test independent on the post-test scores of CA-CM group indicated that $t = -5.755$ there was significant difference

Table 4.6 Comparison of pre-test and post-test scores of CA-CM group

Group	N	Mean	SD	t	*df*	Sig (2 tailed)
Pre-test	32	35.531	5.999	-5.755	31	.000**
Post-test	32	38.375	5.091			

Note. ***p < .01 (Paired sample t-test)*

	N	Correlation	Sig.
Post & Pre CA-CM	32	.886	.000**

The mean pre-test and post-test scores of the SM-CM group was 33.437 and 37.781, and the results of correlations of post-test scores on knowledge acquisition was $r = .602$ that had high positive relationship as shown in Table 4.7. The t-test independent on the post-test scores of CA-CM group indicated that $t = -5.646$ there was significant difference.

Table 4.7 Comparison of pre-test and post-test scores of SM-CM group

Group	N	Mean	SD	t	*df*	Sig (2 tailed)
Pre-test	32	33.437	5.173	-5.646	31	.000**
Post-test	32	37.781	4.484			

*Note. **p < .01 (Paired sample t-test)*

	N	Correlation	Sig.
Post & Pre CA-CM	32	.602	.000**

4.3.3 The difference between the pre-map and post-map of the CA-CM and SM-CM group scores on the KBESCFD model

Table 4.8 Comparison of the pre-map of the CA-CM and SM-CM group scores in six cases on independent sample test

Cases	Scores	N	Mean	SD	t	*df*	Sig (2 tailed)
1	CA-CM	4	45.000	14.212	.699	5	.516
	SM-CM	3	39.000	3.605			
2	CA-CM	6	43.000	21.241	-.088	10	.931
	SM-CM	6	43.833	9.042			
3	CA-CM	4	38.250	14.338	.368	6	.725
	SM-CM	4	33.750	19.788			
4	CA-CM	6	63.000	20.019	3.047	10	.012*
	SM-CM	6	37.166	5.528			
5	CA-CM	6	46.000	11.331	4.030	11	.002**
	SM-CM	7	28.428	2.370			
6	CA-CM	6	34.000	5.059	1.276	10	.231
	SM-CM	6	30.166	5.344			

*Note. *p < .05 (Independent sample t-test)   **p < .01 (Independent sample t-test)*

In pre-map test, there were two cases had great statistically significant.

First, the pre-map test mean scores of CA-CM and SM-CM in steering system faulty diagnosis (case 4) were 63.000 and 37.166 and the t-test result showed that the pre-map test scores of CA-CM and SM-CM were t = 3.047. The t-test result showed that this difference in the mean score is great statistically significant.

Second, the pre-map test mean scores of CA-CM and SM-CM in manual transmission system (case 5) were 46.000 and 28.428. The t-test result showed that the pre-map test scores of CA-CM and SM-CM were t = 4.030. The t-test result showed that this difference in the mean score is great statistically significant.

Table 4.9 Comparison of the post-map of the CA-CM and SM-CM group scores in six cases on independent sample test

Cases	Scores	N	Mean	SD	t	*df*	Sig (2 tailed)
1	CA-CM	4	63.250	16.255	1.521	5	.189
	SM-CM	3	47.000	9.643			
2	CA-CM	6	56.000	23.588	-.144	10	.888
	SM-CM	6	57.500	9.648			
3	CA-CM	4	48.750	21.884	.272	6	.795
	SM-CM	4	44.750	19.602			
4	CA-CM	6	74.000	21.605	3.317	10	.008**
	SM-CM	6	44.500	2.810			
5	CA-CM	6	54.500	15.109	3.225	11	.008**
	SM-CM	7	35.142	4.810			
6	CA-CM	6	46.333	5.006	2.824	10	.018*
	SM-CM	6	38.500	4.593			

*Note. *p < .05 (Independent sample t-test) **p < .01 (Independent sample t-test)*

In post-map test, there were three cases had great statistically significant.

First, the post-map test mean scores on steering system faulty diagnosis (case 4) of both the CA-CM and SM-CM groups were greatly higher than that of the pre-map. The post-map test mean scores were 74.000 and 44.500. The t-test result showed that the post-map test scores of CA-CM and SM-CM were t = 3.317. The t-test result showed that this difference in the mean score is great statistically significant.

Second, the post-map test mean scores on manual transmission system (case 5) faulty diagnosis of both the CA-CM and SM-CM groups were greatly higher than that of the pre-map. The post-map test mean scores were 54.500 and 35.142. The t-test result showed that the post-map test scores of CA-CM and SM-CM were t = 3.225. The t-test result showed that this difference in the mean score is great statistically significant.

Third, The post-map mean scores on automatic transmission system faulty diagnosis (case 6) of both the CA-CM and SM-CM groups were greatly higher than that of the pre-test. The post-map test scores were 46.333 and 38.500. The t-test result showed that the post-map test scores of CA-CM and SM-CM were t = 2.824. The t-test result showed that this difference in the mean score is great statistically significant.

Table 4.10 The technicians' satisfactions towards the KBESCFD model

Statement	*M*	*SD*	Ranking
1. The knowledge transfer of researchers is accuracy and reliability.	4.63	0.72	5
2. The ability is led to explain and propose the generate idea for automotive problem-solving skills	4.29	1.12	13
3. Researcher are articulating the content as a learning themes	4.55	1.06	10
4. The learning profile is completely.	4.81	0.57	3
5. Time management is absolutely.	4.22	1.08	15
6. Researchers have discussion and recommendation in sessions.	4.69	0.83	4
7. Accommodation is absolutely.	4.16	1.24	16
8. Readiness on visualization and audio equipment.	4.58	0.93	8

Table 4.10 The technicians' satisfactions towards the KBESCFD model (Continued)

Statement	*M*	*SD*	Ranking
9. Time frame is absolutely.	4.67	0.94	6
10. Food is absolutely.	4.05	1.13	18
11. The learning outcomes on knowledge increasingly.	4.87	0.73	2
12. Troubleshooters' can be applied at workplace.	4.96	0.41	1
13. Troubleshooters' can declare the description of automotive troubleshooting tasks.	4.52	1.03	11
14. Troubleshooters' raises capacities on thinking skills for developing systematic work.	4.61	0.95	7
15. Troubleshooters' can integrate conceptual framework that employs the problem-based approach.	3.84	1.84	20
16. Troubleshooters' have increasingly on domain knowledge and applications at work completely.	4.23	1.02	14
17. Troubleshooters' can coach and transferability new experience knowledge with colleagues.	4.09	1.64	17
18. Troubleshooters' have able to consulting.	4.47	1.32	12
19. Troubleshooters' have already to apply transferability.	4.56	1.43	9
20. Troubleshooters' have encouraging and motivation for continuously improving productivity.	4.02	2.06	19
Total	**4.44**	**1.10**	

In Table 4.10, technicians' had learning satisfaction at the high level. As a whole, they suggested that applied the knowledge transfer to workplace, knowledge increasingly, and learning profile is completely.