# CHAPTER 3 METHODOLOGY

This chapter highlights the research methodology and procedures used in the study, which consists of the following three phase's section: purposes of the study, sampling, instrument development and testing, methods and procedures, data collection, and data analysis. First, researcher's presents a research process has the following:

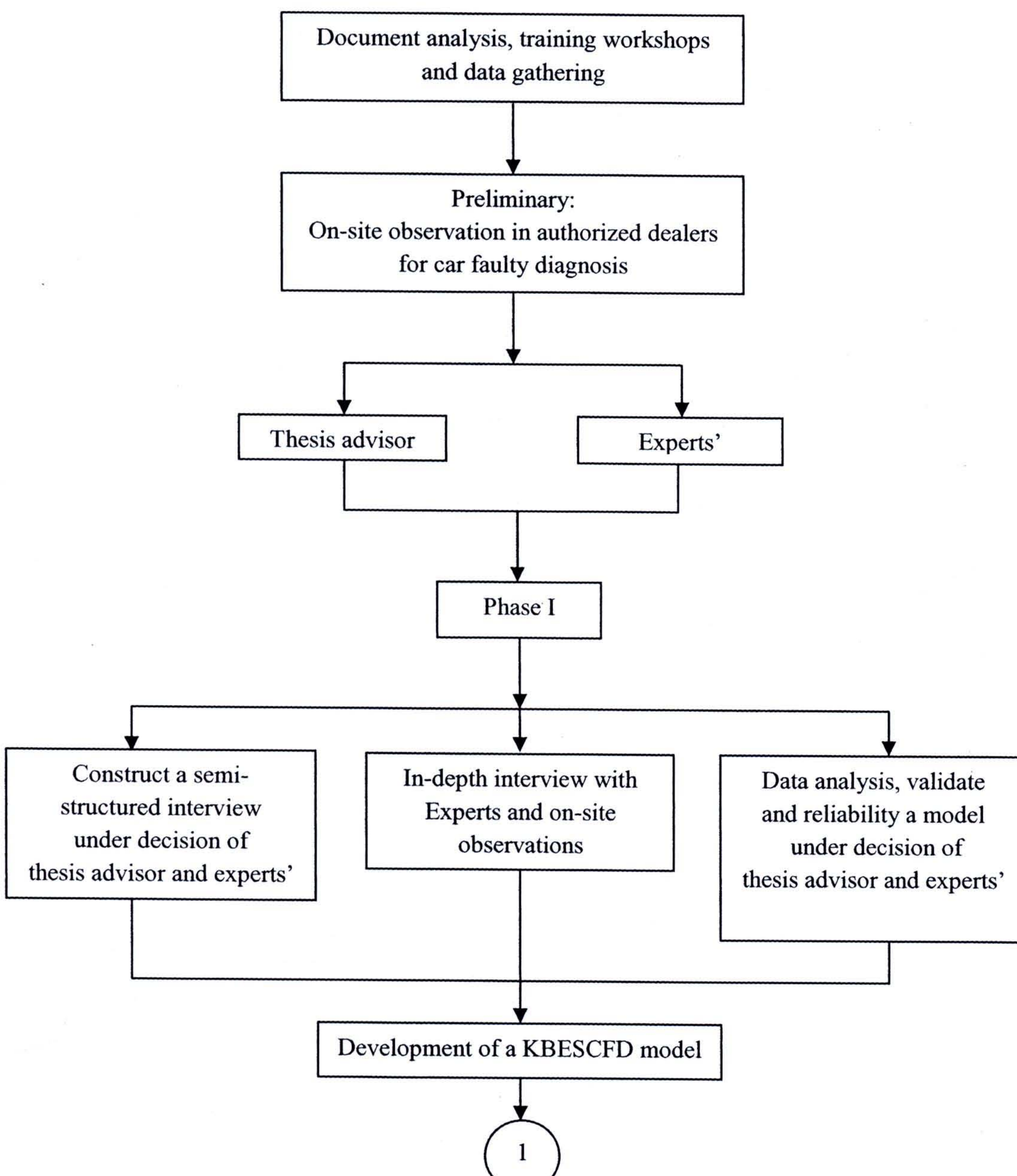



**Figure 3.1** A summarize flowchart in research process

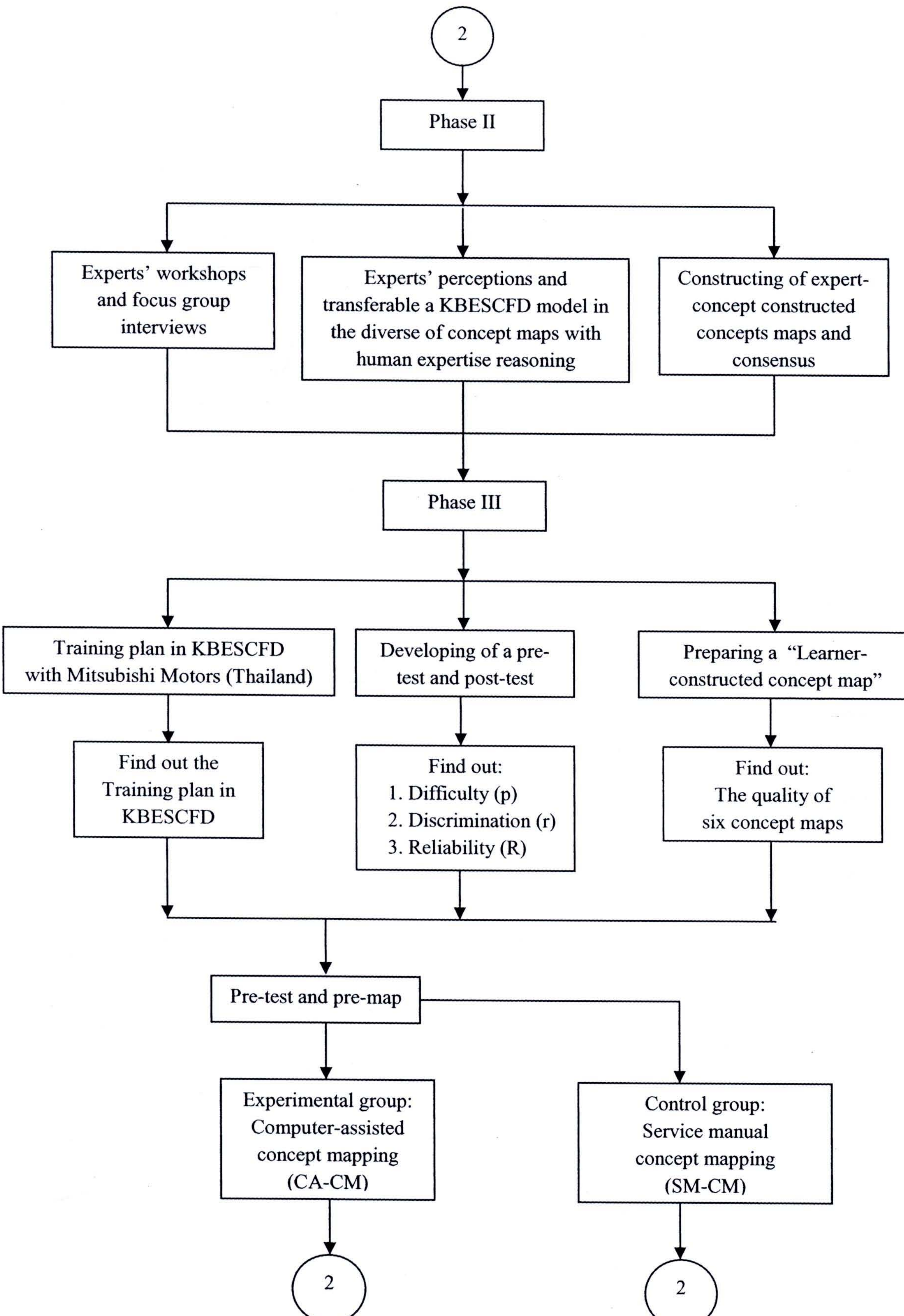



**Figure 3.1** A summarize flowchart in research process (Continued)

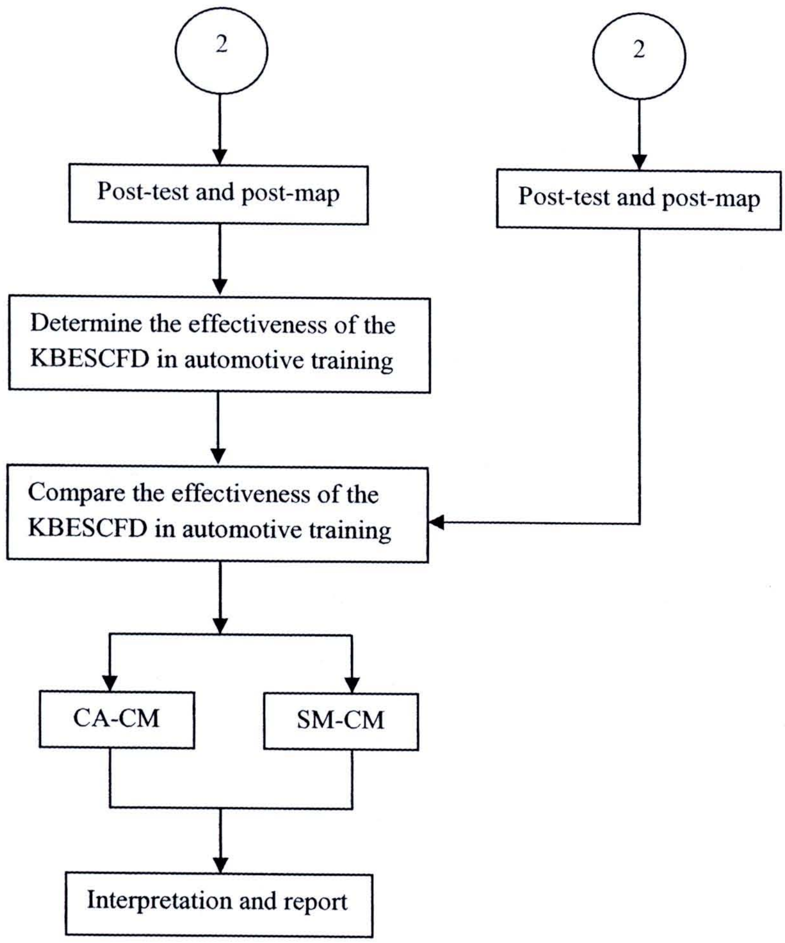



**Figure 3.1** A summarize flowchart in research process (Continued)

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

### 3.1.1 Purpose

To develop a knowledge-based expert system for car faulty diagnosis that provides expert guidance.

### 3.1.2 Design

The qualitative data was collected through documentary analysis, on-site observations, audiotape materials, and interviews a number of in-depth insights. Researcher is designing through review the literature by analyzing and synthesizing what KBESCFD models exist.

Questions that begin with how or what lend themselves to qualitative study (Creswell, 1988). Provide a rationale for selecting the KBESCFD model, which able to derive interdisciplinary initiatives for sustainability. Qualitative research can also be used to gain new insights into problems about which information already exist (Creswell, 1998: Hoepfl, 1997). The study was conducted to the interval time October 2008 – December 2008.

### 3.1.3 Procedures

Researcher was synthesized the collecting qualitative data, and then construct a protocol for conducting. The process was conducted from transcripts to results in the following stages (Creswell, 2008; Gregson, 1998). The study was conducted in five consecutive stages, as follows:

***Stage 1:*** Researcher was constructed the 5 open-ended questions through document analysis and through interviews a number of in-depth semistructured insights and concerning a problem solving training program. It converted an utterance to an observation by recognizing it as significant. A sentence or phrase is not included in the analysis until it is identified as being relevant to the research. The transcript is read carefully with the research question in mind to identify those utterances that must be identified and collected for later study.

***Stage 2:*** Develops the logical relationships that occur in the transcript. These relationships can be with the utterance itself, with the rest of the transcript or with previous literature. This stage begins to attach meaning to and classify the utterance.

***Stage 3:*** Refines the observation in relation to all of the other Stage 2 observations in the entire transcript. This stage moves from the study of one transcript to from relationships across transcripts.

***Stage 4:*** Researcher considers the patterns of inter-theme consistency and contradiction. Redundant themes are combined or eliminated. Themes that do not appear useful for the research question are eliminated.

***Stage 5:*** Identifies the pattern across the themes derived from the entire interview process.

### 3.1.4 Participants

The research involved 11 training managers from 8 well-known the car automobile companies in Thailand who were involved in curriculum development/training program development.

### 3.1.5 Data collection

Each interview was audiotape materials recorded, and the recordings were transcribed for later use. The one-on-one interviews began with casual conversation followed by a description of the scope of the research and the general flow of the interview. The interview followed the basic structure and practices to solve the problems of automotive service technicians' areas (Duffy, 2000). The subject would then describe an in-depth interview would prove for clarification or increase depth of response.

The interviewees used probes, open-ended questions, questions of clarification, and reflective listening to keep the participant on the subjects of theme. The incidents formed one set of data regarding training design and delivery, the problem solving skills training program formed a second set, and the training manager generated problem solving skills training program formed a third.

### 3.1.6 Data analysis

Data analysis of the in-depth interviews used the interview protocol analysis technique (Creswell, 2008; Chamaz, 2006; Creswell & Miller, 2000). Each written transcript was reviewed and highlighted to analyze, design, development, implementation, and evaluation for exceptional contextual conditions in training design and delivery. There was commons conceptual framework on the knowledge-based expert system (KBES) and automotive training environment. Each transcript was reviewed individually to identify consistent themes which could be generalized as a KBES model for that individual. After each transcript was reviewed individually, the set of transcripts was to develop the effective training program which appears across multiple transcripts as shown in Figure 3.2.

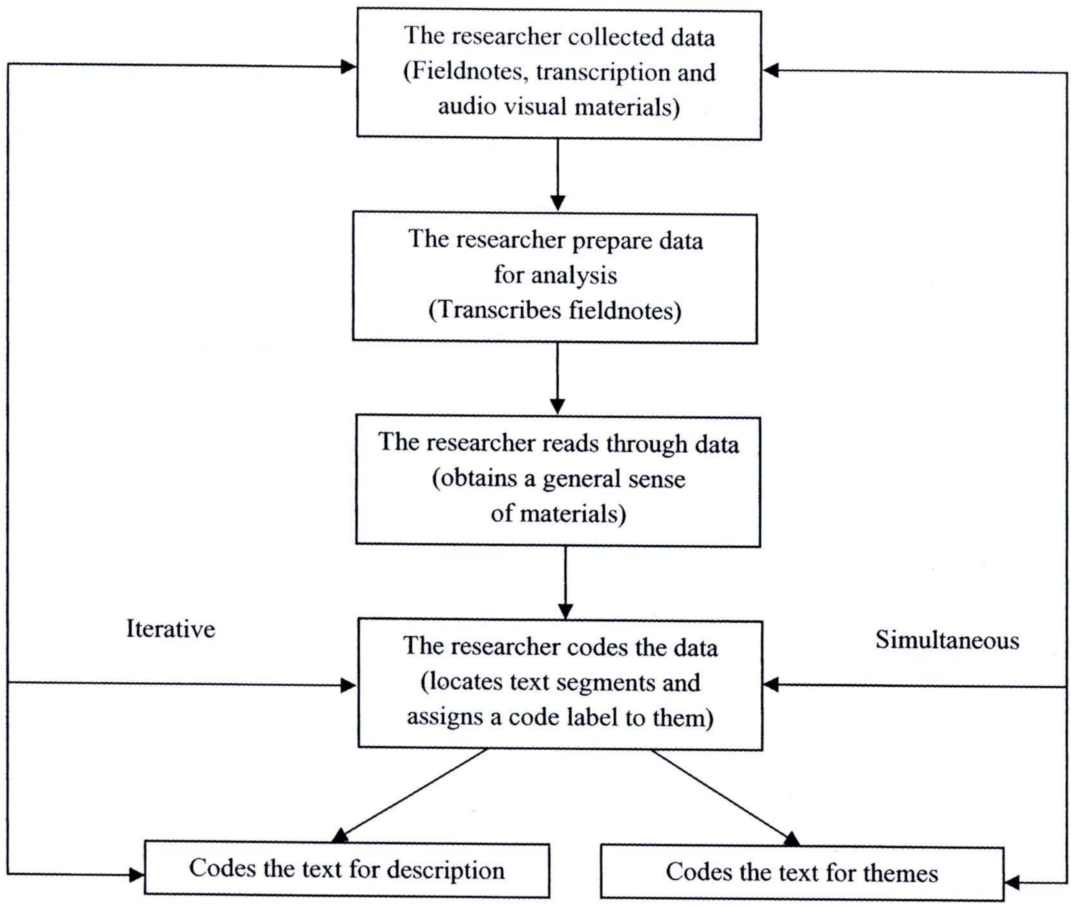



**Figure 3.2** Interview protocol analysis techniques

A systematic design in grounded theory emphasizes the use of data analysis steps of open, axial, and selective coding, and the development of a logic paradigm of the theory generated. The produces for data analysis in the question 2 is grounded theory involve three types of coding procedures: opening coding, axial coding, and selective coding as shown in Figure 3.3 (Creswell, 2008; Chamaz, 2006). Opening coding consists of naming and categorizing data. Experts' transcriptions are reviewed; concepts or themes with similar properties are grouped together. The categories are arranged and rearranged until 'saturated;' that the concepts were similar and should be grouped together.

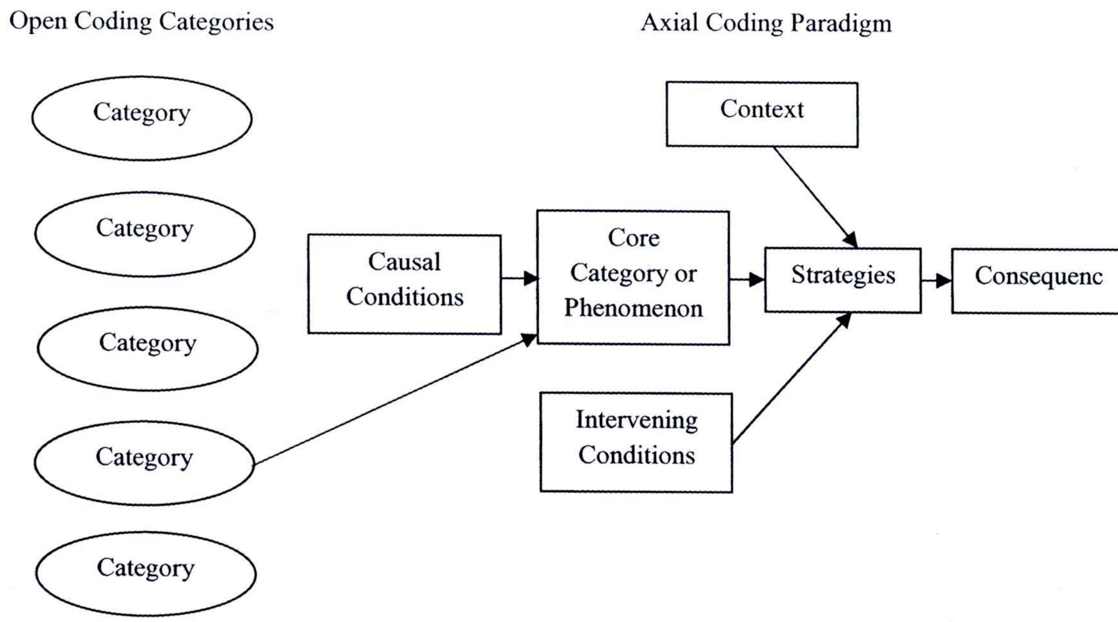



**Figure 3.3** Grounded theory coding from open coding to the axial coding paradigm

To illustrate this process, first examine Figure 3.3. The open coding categories are on the left and the axial coding paradigm on the right. Researchers identify one of the open categories as the core category that is central to a theory. Then, this core category becomes the centerpoint of the axial coding paradigm. Examining, there are six categories of information (Creswell, 2008; Chamaz, 2006):

1. *Causal conditions*–categories of conditions that influence the core category
2. *Context*–the specific conditions that influences the strategies
3. *Core category*–the idea of phenomenon central to the process
4. *Intervening conditions*–the general contextual conditions that influence strategies
5. *Strategies*–the specific actions or interactions that result from the core phenomenon
6. *Consequences*–the outcomes of employing the strategies

In addition, viewing this coding paradigm from left to right that the causal conditions influence the core phenomenon, the core phenomenon and the context and intervening conditions influence the strategies, and the strategies influence the consequences. In selective coding is the process of integrating and refining the theory.

### 3.1.7 Research reliability and validity

At this point, original transcript text was retained and attached to the KBESCFD model as further definition. All of analysis to this point was done blindly. The transcripts were tagged with an identification number and the analyst did not know the name of the participant. Furthermore, the analyst did not know if the transcripts were from exceptional or non-exceptional participants. A document analysis was conducted to describe, interpret and compare information obtained in this research. The triangulation method was referred to enhance reliability and validity. Discussion and checking of the data with other research members helped isolate discrepancies, giving rise to a new research issue and reinforcing validity.

### 3.1.8 A proposed of KBESCFD model

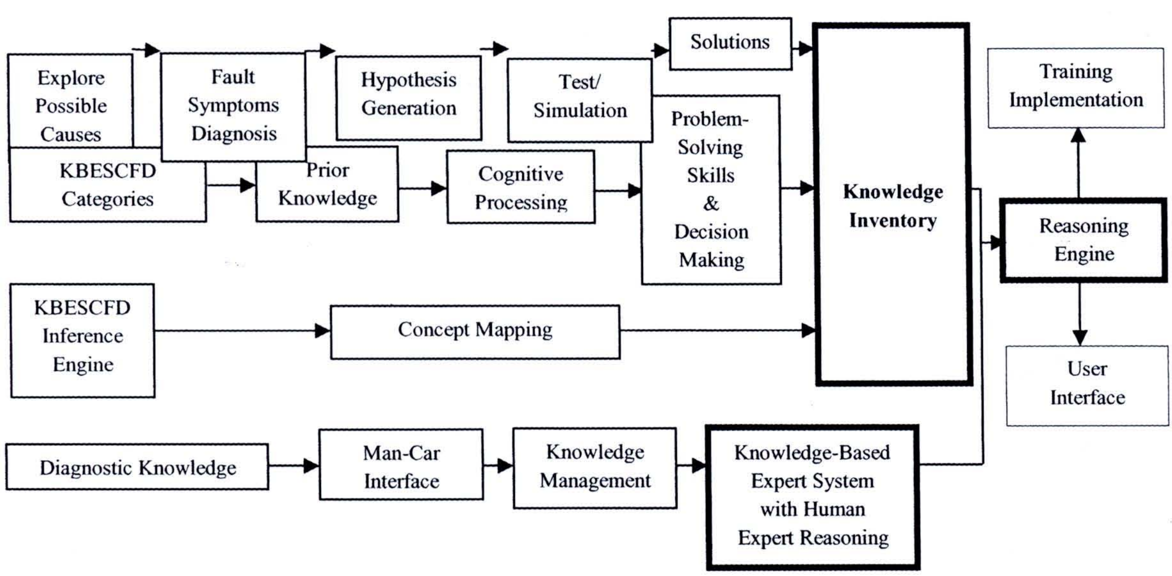



**Figure 3.4** A KBESCFD model

In Figure 3.4, a KBESCFD model consisted of five major stages as follows: 1) automotive problem-solving efficiency process; 2) cognitive domain knowledge; 3) inference engine process; 4) diagnostic knowledge; and 5) reasoning engine. There are sub-stages in each of the major stages have the following:

1. Automotive problem-solving efficiency process
    1.1 Explore possible causes
    1.2 Fault symptoms diagnosis

1.3 Hypothesis generation

1.4 Test/simulation

1.5 Solutions

2. Cognitive domain knowledge

2.1 Problem clarification of KBESCFD categories

2.2 Prior knowledge

2.3 Cognitive processing

2.4 Problem-solving skills and decision-making

3. Inference engine process

3.1 Generating discussion and recommendation concerned into KBESCFD inference engine

3.2 Reviewing and creating of the concept mapping

4. Diagnostic knowledge

4.1 Modification of the man-car inference

4.2 Collecting the knowledge management

4.3 Submitting to the knowledge-based expert system with human expert reasoning

5. Reasoning engine

5.1 KBESCFD articulated by the user interface

5.2 Distribution of the knowledge inventory for the future practicing

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

### 3.2.1 Purpose

To implement a knowledge-based expert system for car faulty diagnosis that supports the functionality required in extended for modifications and additions.

### 3.2.2 Participants

Experts' involved the consensus in a KBESCFD model and employed the expert-concept map task was designed and developed by among a team of six participants (four automotive training instructors and two automotive service technician supervisors). The study engaged in Mitsubishi Motors (Thailand) supported project to develop such organizes for problem solving skills. The research was conducted to experts at Training center (Room A), Mitsubishi Motors (Thailand) on January 14 and February 10, 2009.

### 3.2.3 Materials and procedure

A KBESCFD model was transferability through both of the knowledge acquisition and knowledge representation step by step. They were generating the concept maps also included to construct early by using paper-pencil and develop towards IHMC Cmaps Tools version 4.18 (Institute for Human and Machine Cognition, 2009). Researchers were introduced experts to concept mapping in the context of procedural knowledge. The experts were practiced by filling in portions of a partially completed map that represented the essential problem-solving skill in term of ill-structured problem, a domain that can be synthesized on the real-time solving the problems. Problems are familiar at the workplace.

The team, after workshop, discussion, argument, and reflection, agreed on a list of ten nouns (disagreed two nouns) and three verbs to represent the design process. The nouns are: 1) Diesel engine faulty diagnosis; 2) Multi-point injection engine (MPI) faulty diagnosis; 3) Common-rail diesel direct injection system (CRD) faulty diagnosis; 4) Automatic transmission (A/T) faulty diagnosis; 5) Wheel alignment faulty diagnosis; 6) Steering system faulty diagnosis; 7) Suspension system faulty diagnosis; 8) Brake system faulty diagnosis; 9) Manual transmission system (M/T) faulty diagnosis; and 10) magnetic clutch faulty diagnosis.

The verbs are: (1) Causes of Problem; (2) Problem Occur; and (3) Alternate Solutions (Hall, 1988; Jonassen, Beissner, & Yacci, 1993; Jonassen, 1997, 2000, 2004; Jonassen & Hernandez-Serrano, 2002; Jonassen & Hung, 2006).

### 3.2.4 Data Collection

The data, in the form of concept maps and workshop and focus group discussion and interview audio-tapes recorder, were gathered at two stages in the process: workshop tutorial session and focus group discussion session. The experts were interviewed at two stages. Completed concept maps were examined by the researcher and then returned before interviews commenced. All interviews and focus group discussion were audio-recorded and later transcribed for further analysis. This procedure allowed the researchers to gain an analysis of the KBESCFD and concept maps constructed showed how the expertise used the concept mapping tool to transfer their car faulty diagnosis in the reliability of solutions that they revised their maps.

### 3.2.5 Concept mapping validity and reliability

The final interview with each expert took place in the comments and suggestions of their completed concept map. They were asked to explain and demonstrate how they constructed their concept map. At the view points, researchers asked clarifying questions or re-stated their descriptions. Numerous journals related into career and technical research areas were also examined. Data analysis of the in-depth interviews used the Protocol Analysis Technique (Creswell, 2008; Charmaz, 2006) and content analysis.

Each written transcript was reviewed and highlighted. There was commons conceptual framework on ill-structured problem. Each transcript was reviewed individually to identify consistent themes which could be generalized as problem solving skills for that individual. After each transcript was reviewed individually, the set of transcripts was to develop the effective training program which appears across multiple transcripts. The data was analyzed by using content analysis.

### 3.2.6 Analysis of the concept maps

A KBESCFD model norms that used to recommend within the evaluate 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 rubric deals with three common map structures which may be interpreted as indicators of progressive levels of understanding:

1. ***Spoke,*** a structure in which all the related aspects of the topic are linked directly to the core concept, but are not directly linked to each other *retrieval* and *reuse* in CBR:

2. ***Chain***, a linear sequence of understanding in which each concept is only linked to those immediately above and below with *revision* in CBR; and

3. ***Net***, a network both highly integrated and hierarchical, demonstrating a deep understanding of the topic with *retention* in CBR.

As 'invalid links' are seen as being of equal important to 'valid links' (in terms of expertise's-awareness), the time-consuming (and sometimes arbitrary) process of assessing the validity of links is avoided. The simplicity of this classification scheme makes it more likely that it could be adopted for workplace use and yet it fulfills the criteria for an effective qualitative scheme.

The scheme differentials maps in terms of their complexity; resilience in accommodating additions; the establishment of a context of for the key concepts; degree of appreciation of a wider viewpoint and its relationship with the 'expert' view. Finally, the decision based on experts' selected the six maps absolutely.

### 3.2.7 Research-criteria (RC) assessment rubric for the concept maps task

A scoring system to evaluate the concept map (Kinchin & Hay, 2000) which the scoring system is an assessment rule-based scoring system adapts from Novak's Scoring Protocol (Novak & Gowin, 1984) as shown in Table 3.1 (Ausubel, 2000; Jonassen, Beissner, & Yacci, 1993; Koul, Clariana, & Salehi, 2005; Novak & Gowin, 1994).

**Table 3.1** Research-criteria (RC) assessment rubric for the concept maps task

| Research Criteria | Description | Weighting | Interpretation |
|---|---|---|---|
| RC 1 | *Content* – inclusion of the problem occurs (concepts) | 50 – 41%<br>40 – 31%<br>30 – 21%<br>Lower 20% | Excellent<br>Appropriate<br>Moderate<br>Fail |
| RC 2 | *Hierarchy* – concepts organized from initial skills towards the advanced skills of problem occurs | 40 - 31%<br>30 – 21%<br>20 – 11%<br>Lower 10% | Excellent<br>Appropriate<br>Moderate<br>Fail |
| RC 3 | *Links/Node* – computed average number of links per node | 50 – 41%<br>40 – 31%<br>30 – 21%<br>Lower 20% | Excellent<br>Appropriate<br>Moderate<br>Fail |
| RC 4 | *Branching* – count of nodes with greater than 2 outgoing links | 30 – 21%<br>20 – 11%<br>Lower 10% | Excellent<br>Moderate<br>Fail |
| RC 5 | *Merging* – count of nodes with greater than 1 ingoing links | 30 – 21%<br>20 – 11%<br>Lower 10% | Excellent<br>Moderate<br>Fail |
| RC 6 | *Linking Words* – quality of linking words | 50 – 41%<br>40 – 31%<br>30 – 21%<br>Lower 20% | Excellent<br>Appropriate<br>Moderate<br>Fail |

## 3.3 Phase 3: Determine the effectiveness of the knowledge-based expert system for car faulty diagnosis

### 3.3.1 Purpose

To determine the effectiveness of the knowledge-based expert system for car faulty diagnosis in automotive troubleshooting tasks.

### 3.3.2 Design

This study took place during the second of a six-day session at the training centre of Mitsubishi Motors (Thailand) in January to March, 2010. A quasi-experimental design was chosen, involving non-random assignment into two groups, and this used a pre-test-post-test control group design with a KBESCFD model as shown in Figure 3.5. Both knowledge acquisition and concept maps were conducted to consider the effects of scores.

Pre-and Post-test Design Time →

| | | | |
|---|---|---|---|
| Select Experimental Group | Pre-test | Experimental Treatment | Post-test |
| Select Control Group | Pre-test | No Treatment | Post-test |

**Figure 3.5** Quasi-experimental design

### 3.3.2.1 Prompted learning strategy

The study can be divided into (a) a computer-assisted concept mapping (CA-CM) group and (b) a service manual (paper-pencil) study plus discussion (SM-CM) group. Prior to the experiment, the concept mapping group and the service manual study plus discussion group completed the Mitsubishi Automotive Technology Test (MATT) pre-test. This involved studying the six tasks on automotive troubleshooting tasks that are assessed with the KBESCFD model. At the end of the experiment, all of the troubleshooters completed post-test.

### 3.3.2.2 Strategy demonstration.

At the beginning of the study, the researchers explained the basic information on the KBESCFD model. Then the Mitsubishi automotive technology test was conducted as a pre-test and post-test in order to assess the level of the knowledge acquisition and include the maps as a knowledge. Concept mapping and how to prepare concept maps was explained to the troubleshooters in the experiment group, providing examples via the internet also included using IHMC Cmaps Tools version 4.18 (Institute for Human and Machine Cognition).

## 3.3.3 Participants

Fifty practitioners attending the training centre of Mitsubishi Motors (Thailand) volunteered to participate in this study. Participants included 64 males, and divided 2 groups among 32 technicians'. All of the participants were Mitsubishi Motors (Thailand) and dealers in automotive service technicians.

### 3.3.4 Procedures

#### 3.3.4.1 Treatment procedures

Class activities were implemented the KBESCFD model with the six session day as shown in Table 3.2. Technicians were informed about Mitsubishi automotive troubleshooting tasks.

The CA-CM group was exposed to create maps in six tasks scenarios which developed through the following steps (Johnson et al., 1993) as shown in Figure 3.6:

1. use many observation in a sequence of simple decisions as follow as the KBESCFD model;
2. use general search procedures that are not dependent on actual system or fault;
3. search to find faulty symptoms component based on KBESCFD categories; and
4. search through systems to identify appropriate subsystem, state, or component for describing in the reasoning engine.

**Table 3.2** Treatment procedures in this study

| **Session** | **Date** | **Troubleshooters ($N$ = 64)** | | **Treatment** |
|---|---|---|---|---|
| | | **Experimental** | **Control** | |
| 1 | January 28, 2010 | 4 | 3 | Diesel Engine |
| 2 | February 2, 2010 | 6 | 6 | MPI |
| 3 | February 4, 2010 | 4 | 4 | CRD |
| 4 | February 11, 2010 | 6 | 6 | Steering system |
| 5 | March 2, 2010 | 6 | 7 | M/T |
| 6 | March 4, 2010 | 6 | 6 | A/T |
| | Total | **32** | **32** | |

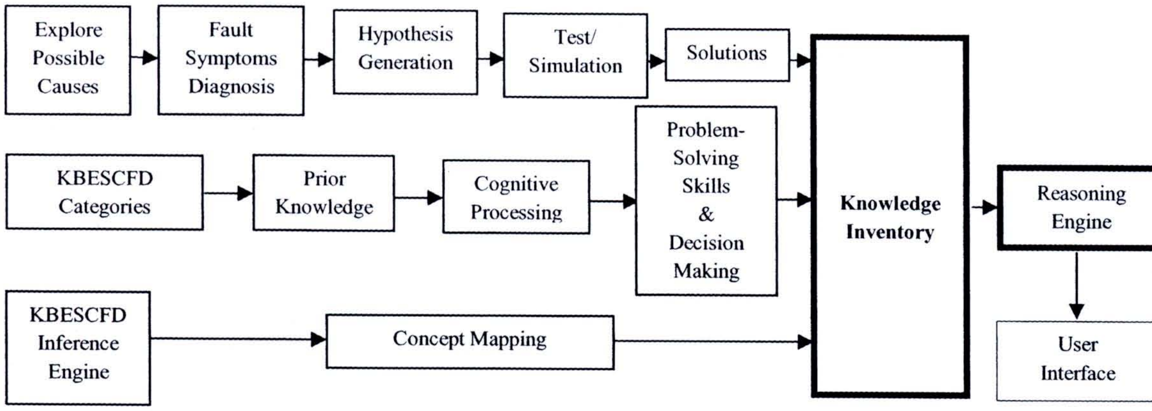



**Figure 3.6** CA-CM group performed base on the KBESCFD model

Hence, they were solved step by step based on (Jonassen, 1997) have the following:

1. Introduction of the problem situation: Ill-structured problems were introduced into each task.

2. Opinions about the problem: Troubleshooters delivered their ideas about the problem and select the tools and procedural.

3. Prior knowledge about the problem: Troubleshooters shared their prior knowledge on the concept maps.

4. Required information to solve the problem: Troubleshooters determined and decision the type and extent of information and previous experience necessary to solve the problem.

5. Solving process: addressing the faulty symptoms and reflected on their solves.

6. Solution process: Using their own experiences and created their action solution to a potential solving the problem.

7. Evaluation: the evaluation of the concept maps was setting at 100 points each task. The rubric score were developed by Novak and Gowin (1984):

   7.1 Relationships: ***Retrieval*** one point for each valid proposition

   7.2 Hierarchy: ***Reuse*** five points for each level of hierarchy

   7.3 Cross-links: ***Revision*** ten points for each valid cross link

   7.4 General to specific example: ***Retention*** one point for each valid example.

The SM-CM group, on the other hand, was provided with the summary each day. They were exposed to traditional learning and training creates concept maps with paper-pencil as well. The six tasks as shown in Table 3.3 on automotive problem space that are assessed on computer-assisted concept maps were explained to the troubleshooters in the experiment group.

The participants identified both knowledge acquisition and create concept maps; consequently, fault symptoms, construct problem space, generate and verify solutions. They were also explained to the troubleshooters in the control group using a service manual study plus discussion method.

### 3.3.5 Instrumentations

#### 3.3.5.1 Knowledge acquisition test

The Mitsubishi Automotive Technology Test (MATT) used to measure the cognitive domains in the automotive troubleshooting tasks. A 50-item and points knowledge acquisition test was originally developed by seven experts of the Mitsubishi Motors (Thailand) Co., Ltd, and used a multiple-choice format with four response options for each item. The validity of the content of this test was evaluated by five professors from the office of the Vocational Education Commission and the director of the Department of Skill Development. The Kuder-Richardson (KR20) measure of internal consistency for the overall current sample is .89 (Creswell, 2008).

**Table 3.3** Phases in the study

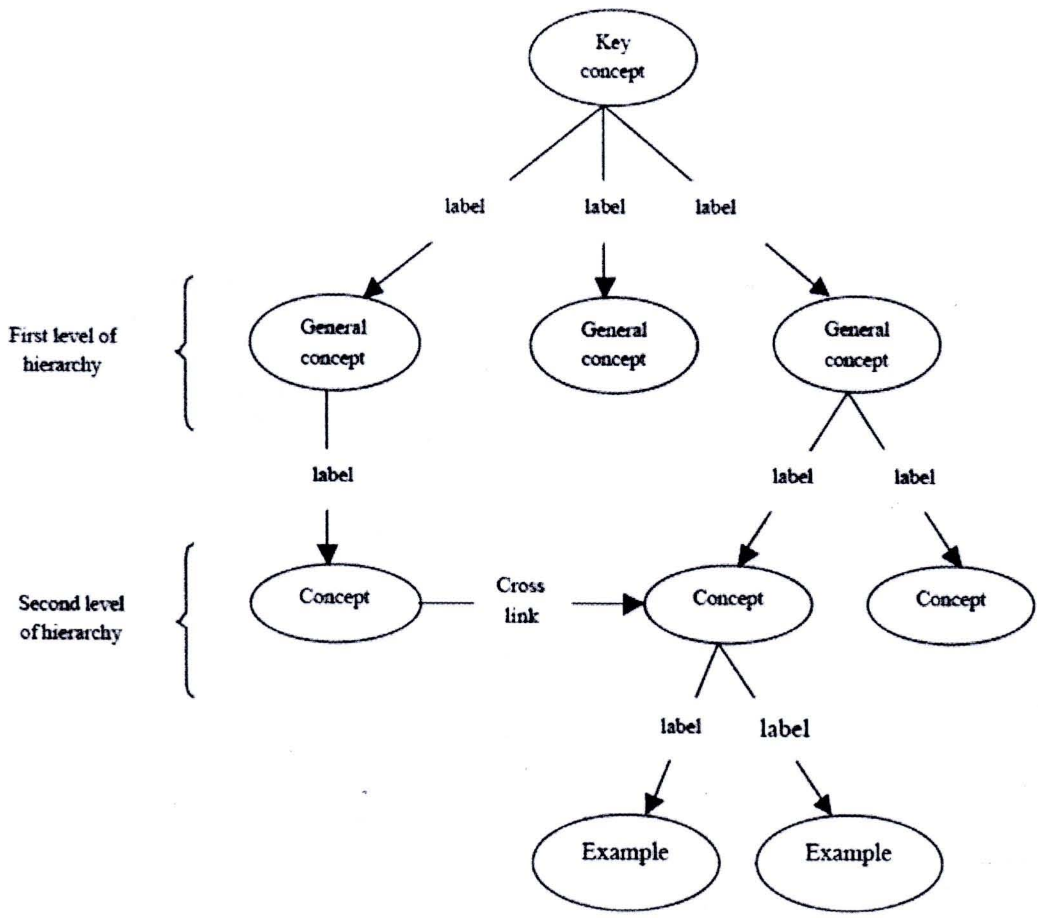
| | | Experimental Group | | Control Group |
|---|---|---|---|---|
| **Pre-testing** | | | | |
| | Day 1: | CA-CM Diesel engine | Day 1: | SM-CM Diesel engine |
| | Day 2: | CA-CM MPI engine | Day 2: | SM-CM MPI engine |
| | Day 3: | CA-CM CRD system | Day 3: | SM-CM system |
| | Day 4: | CA-CM Steering system | Day 4: | SM-CM Steering system |
| | Day 5: | CA-CM M/T system | Day 5: | SM-CM M/T system |
| | Day 6: | CA-CM A/T system | Day 6: | SM-CM A/T system |
| **Post-testing** | | | | |

### 3.3.5.2 Knowledge representation test

For the concept mapping, the practitioners drew their concept maps using computer-assisted techniques base on the KBESCFD model. The concept maps were evaluated on a 100-point scale. The session began with a 30-minute introduction to concept mapping strategy. The troubleshooters received handouts and downloaded IHMC CmapsTool, which included an introduction to creating concept mapping, a list of the characteristics of concept maps, and examples of well-constructed and poorly-constructed concept maps by using Novak Scoring Protocol (Novak & Gowin, 1984).

### 3.5.3.3 Validity of concept mapping

The process is that compares the "learner-constructed concept map" and the "expert-concept constructed concept map". The judgment of concept mapping is combining expert's consensus and Novak Scoring Protocol. This evaluation strategy Novak and Gowin (1984) noted that "there is also an apparent arbitrariness in scoring concept maps as shown in Figure 3.7. The concept maps have covered the three components of a KBESCFD model: 1) car faulty diagnosis procedural; 2) KBESCFD categories; and 3) KBESCFD inference engine. All maps can be evaluated and recorded as similar as the knowledge inventory (database) for applying users interface as well.




| | | | |
|---|---|---|---|
| Propositions (if valid) | score | = 1 x 8 = | 8 |
| Hierarchies (if valid) | score | = 5 x 2 = | 10 |
| Cross-links (if valid) | score | = 10 x 1 = | 10 |
| Examples (if valid) | score | = 1 x 2 = | 2 |
| | | Total | 30 |

**Figure 3.7** Evaluation of concept maps by the structural scoring method (Novak & Gowin, 1984)

A KBESCFD model was employed to the construct map process is shown as Figure 3.8. The six expert-concept maps was evaluated in raters rubric scoring that consisted of (1) Diesel engine faulty diagnosis (Figure 3.9); (2) Multi-point injection engine (MPI) faulty diagnosis (Figure 3.10); (3) Common-rail diesel direct injection system (CRD) faulty diagnosis (Figure 3.11); (4) Steering system faulty diagnosis (Figure 3.12); (5)

Manual transmission system (M/T) faulty diagnosis (Figure 3.13); and (6) Automatic transmission (A/T) faulty diagnosis (Figure 3.14).

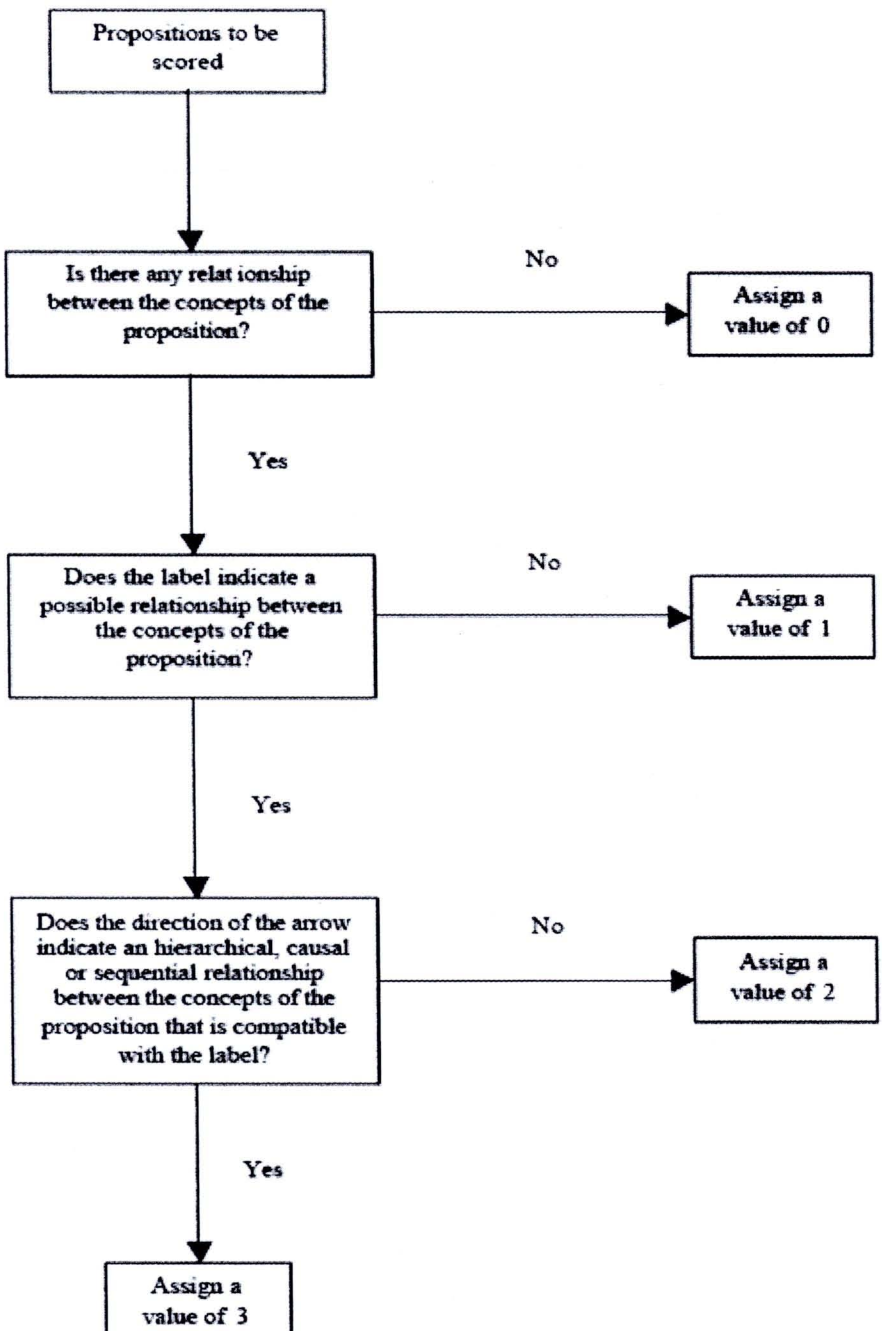



**Figure 3.8** Interpretation a flowchart of concept maps by the structural scoring method (Novak & Gowin, 1984)

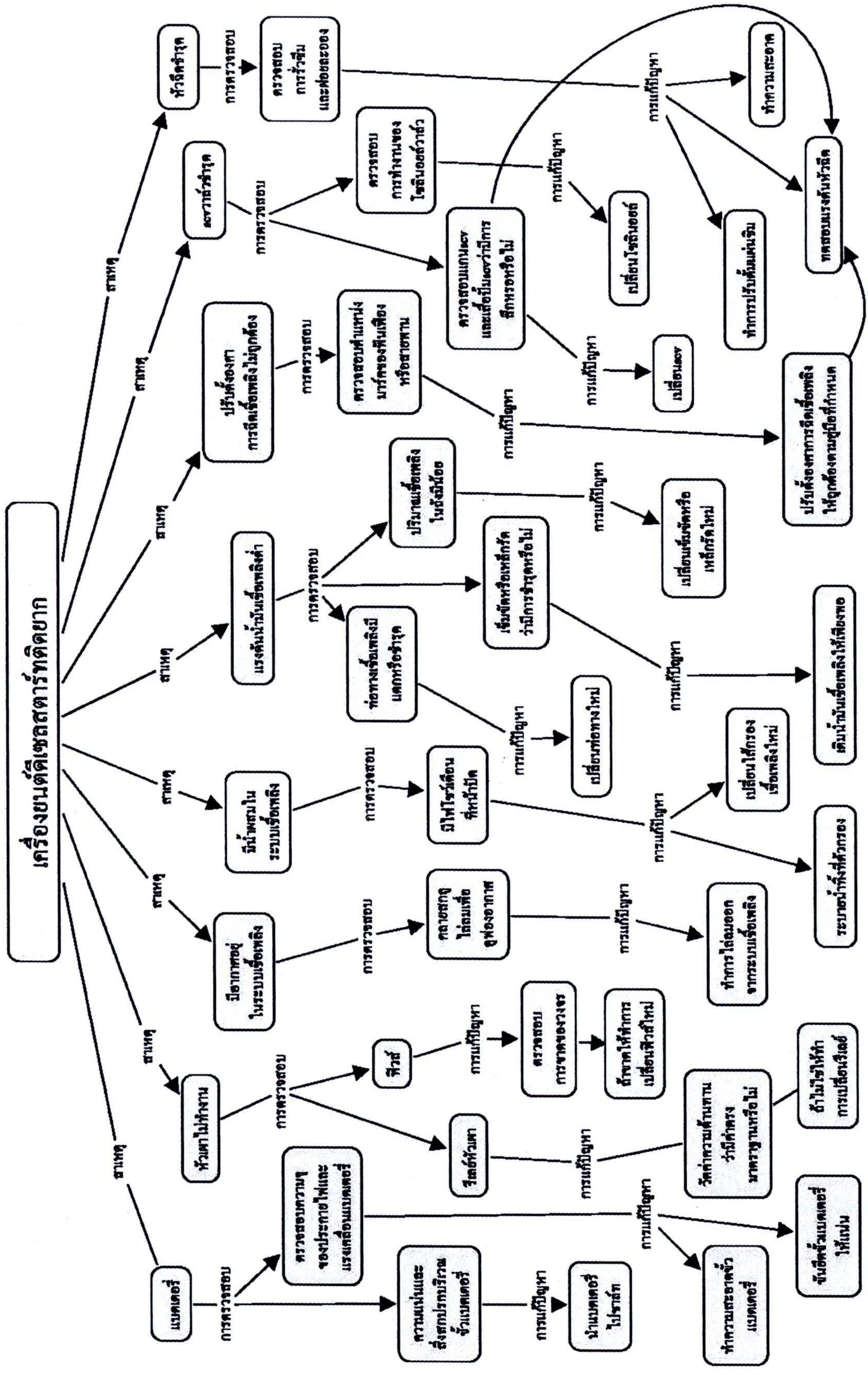


**Figure 3.9** Diesel engine faulty diagnosis symptom concept maps

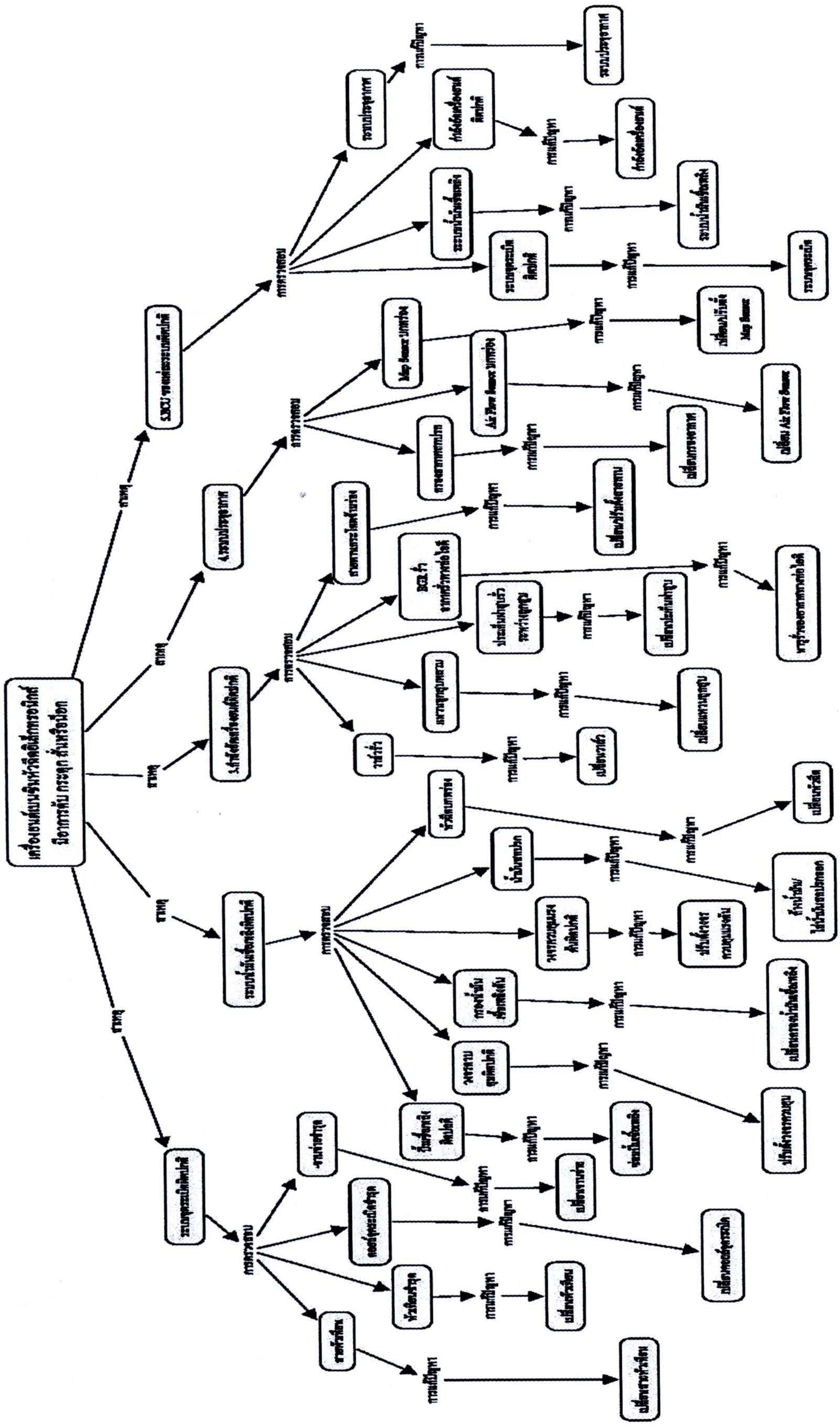


**Figure 3.10** MPI engine faulty diagnosis symptom concept maps

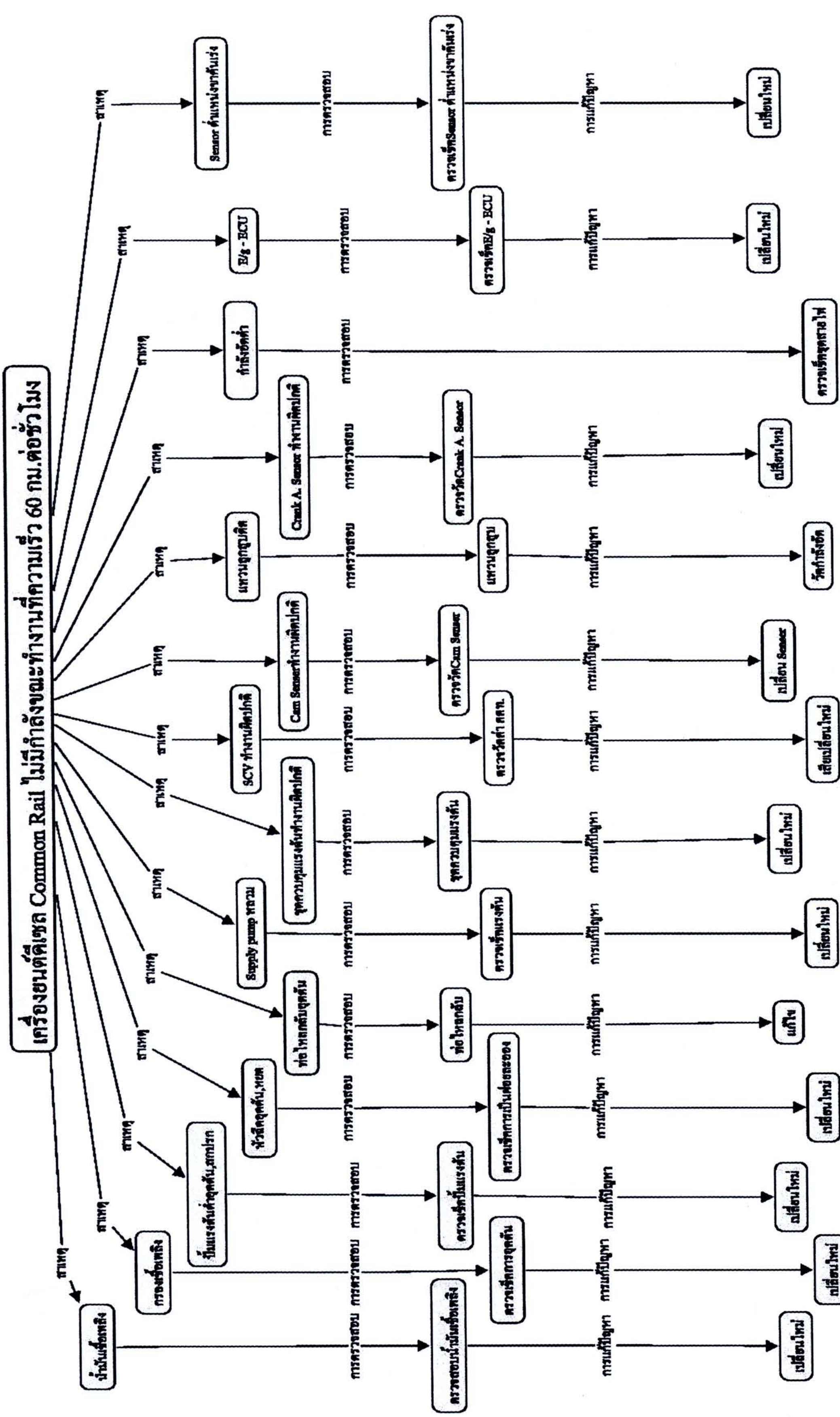



**Figure 3.11** CRD engine faulty diagnosis symptom concept maps

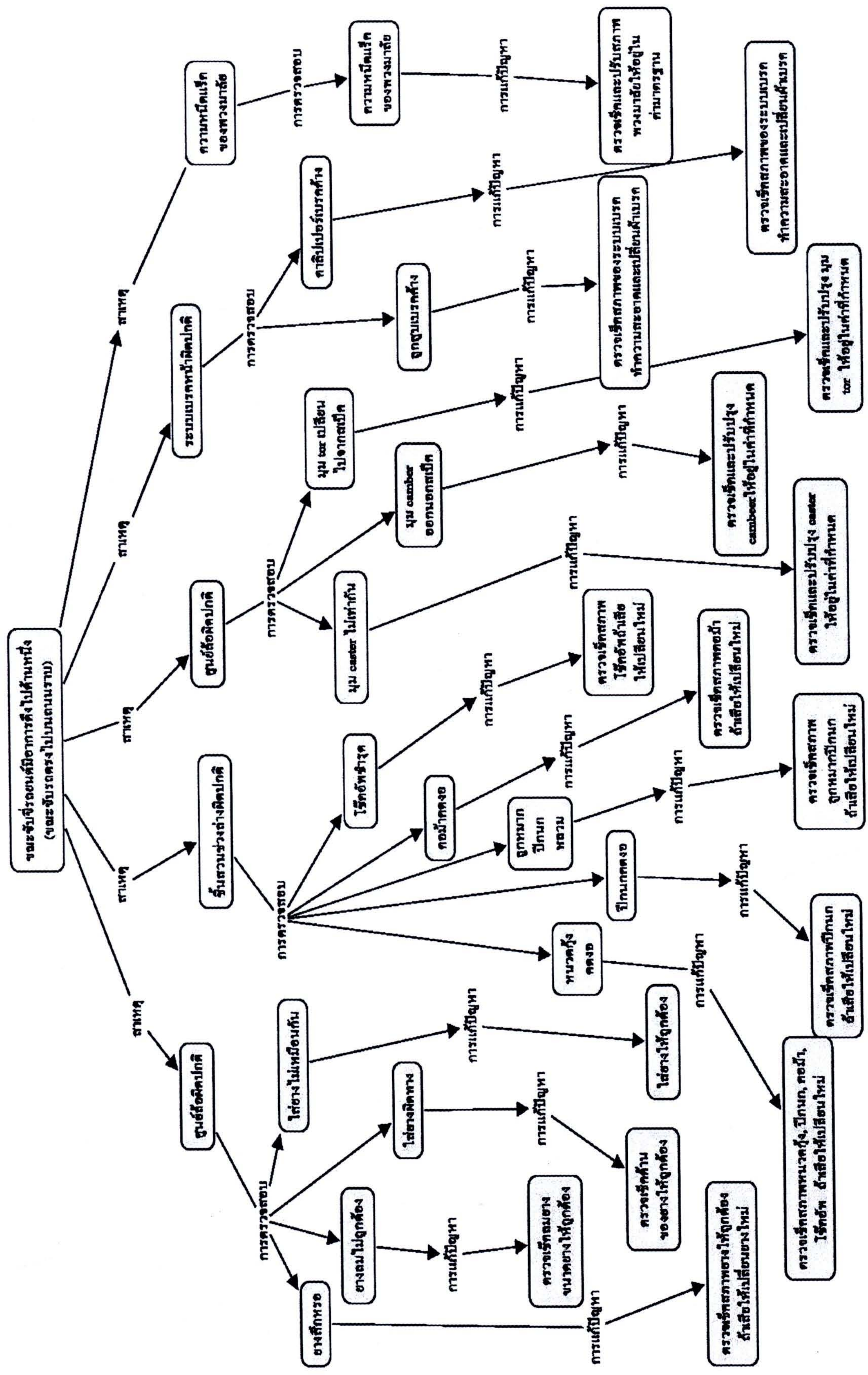


**Figure 3.12** Steering system faulty diagnosis symptom concept maps

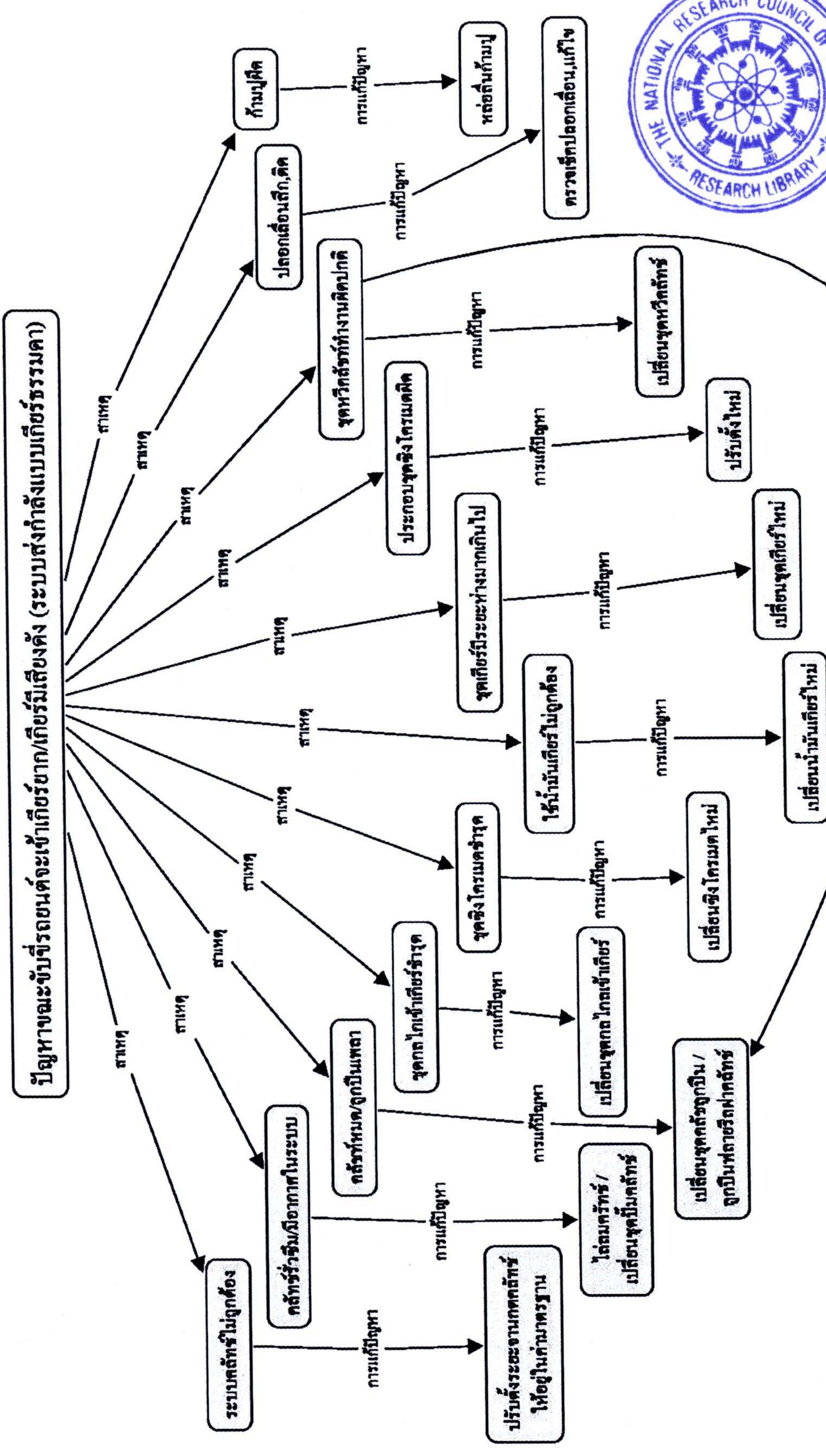



**Figure 3.13** Manual transmission system faulty diagnosis symptom concept maps

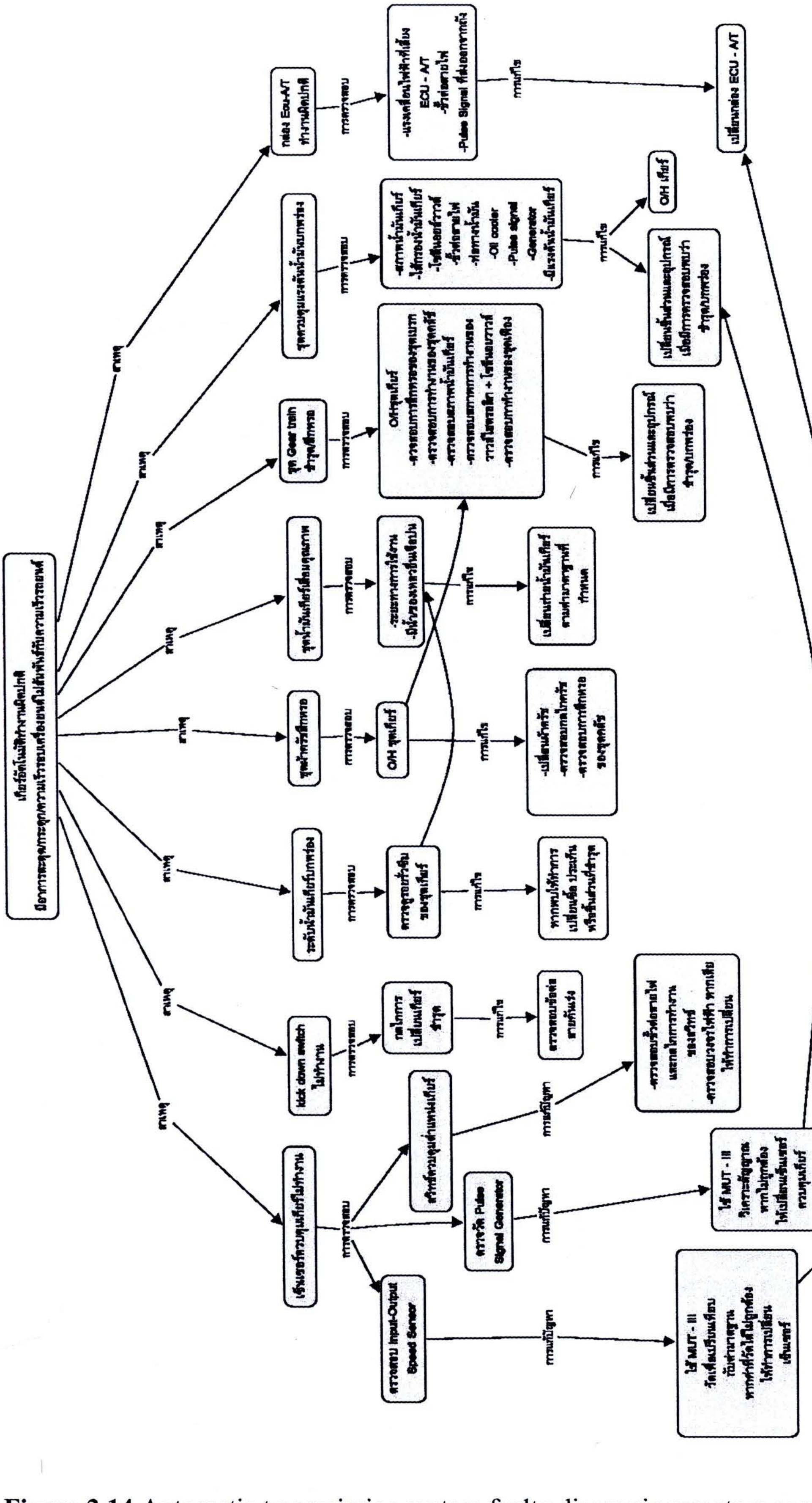


**Figure 3.14** Automatic transmission system faulty diagnosis symptom concept maps

The criterion strategy of six experts-concept maps by the Novak Scoring Protocol method can evaluate as follow as Table 3.4.

**Table 3.4** The criterion strategy of six experts-concept maps by the Novak Scoring Protocol method

| **Session** | **Description** | **Scores** | | | | **Total** |
|---|---|---|---|---|---|---|
| | | **Propositions (if valid)**<br><br>**1 point** | **Hierarchies (if valid)**<br><br>**5 points** | **Cross-links (if valid)**<br>**10 points** | **Examples (if valid)**<br><br>**1 points** | |
| 1 | Diesel engine faulty diagnosis | 1 x 42 | 5 x 2 | 10 x 2 | 1 x 17 | 94 |
| 2 | Multi-point injection engine (MPI) faulty diagnosis | 1 x 44 | 5 x 2 | 0 | 1 x 22 | 66 |
| 3 | Common-rail diesel direct injection system (CRD) faulty diagnosis | 1 x 41 | 5 x 2 | 0 | 1 x 14 | 65 |
| 4 | Steering system faulty diagnosis | 1 x 35 | 5 x 2 | 0 | 1 x 15 | 60 |
| 5 | Manual transmission system (M/T) faulty diagnosis | 1 x 22 | 5 x 2 | 10 x 1 | 1 x 11 | 53 |
| 6 | Automatic transmission (A/T) faulty diagnosis | 1 x 29 | 5 x 2 | 10 x 4 | 1 x 11 | 90 |

For practicum, CA-CM and SM-CM groups have no limited in thinking processes and or generate idea to verify automotive problem solving skills. The criterion strategy is guidance to relate the real-world problem, if troubleshooters do able to new existence knowledge those implications on concept maps (Amadieu, Gog, Paas, Tricot, & Marine, 2009; Akinsanya & Williams, 2004; Cline, Brewster, Fell, 2010; Hao, Kwok, Lau, & Yu, 2010; Haugwitz, Nesbit, Sandmann, 2010; Novak, 1990; Novak & Gowin, 1984; Hilbert & Renkl, 2009; Tzeng, 2009).

#### 3.5.3.4 Satisfaction survey

A questionnaire was raised by technicians after finished all session. Twenty items was collected through five rating scales. The reliability of questionnaire was 1.00 by experts.

### 3.3.6 Data collection

#### 3.3.6.1 Knowledge inventory

Technicians were given a hand-out with 6 Mitsubishi automotive troubleshooting tasks to solve. For each problem statement, a 'identify fault symptoms' order of steps will always lead to multiple alternative solutions and apply. All 6 tasks could be solved using computer-assisted concept mapping (CA-CM) in the experiment group, and the service manual concept mapping (SM-CM) in the control group.

#### 3.3.6.2 Assessments

The pre-test post-test had assessments of 50-items knowledge acquisition (e.g., identify the problem, symptoms analysis, using of electrical and electronic instruments, Mitsubishi utilize test, problem-solving success, decision-making, quality control, and knowledge transfer) and experience in problem solving. The knowledge acquisition items assessed troubleshooters' ability to solve automotive tasks. At post-test, troubleshooters completed the full assessment in the day. At pre-test, troubleshooters completed a subset of the overall assessment – all the knowledge acquisition items.

### 3.3.7 Data analysis

Descriptive statistics were used to illustrate the CA-CM and the SM-CM of the participants for each measurement and a questionnaire. Data was analyzed by descriptive analysis mean, standard deviation; paired-sample t-tests were conducted to see the effects of both scores and t-test independent-sample was inferential statistically. At the inception of interpreting significance of the results, the probability value was yielded at .05 level. Statistical computations were conducted using Statistical Package for Social Science (SPSS).