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Effects of a Computer-Assisted Concept Mapping Learning Strategy on Automotive Troubleshooting Tasks

[1]Weerayute Sudsomboon and [2]Anusit Anmanatrakul
[1]Learning Innovation in Technology Program, [2]Department of Mechanical Technology Education,
Faculty of Industrial Education and Technology,
King Mongkut's University of Technology Thonburi, 126 Pracha-UTIS Road,
Bangmod, Toong-Kru, 10140 Bangkok, Thailand

Abstract: This study investigated how the computer-assisted concept mapping learning strategy employed in the Troubleshooting Learning Environment (TLE) influenced novice troubleshooters diagnose faulty systems and repair. The pre- and post-test control group design was used in the study. The participants (N = 50) included troubleshooters who were enrolled at Mitsubishi motors (Thailand). Participants attended a 5 days learning course. The group taking part in the experiment attended the computer-assisted concept mapping whereas the control group attended the traditional learning. Each group consisted of 25 practitioners. Data collection tools consisted of multiple-choice troubleshooting tasks and participants' concept maps. The results revealed that learning in the computer-assisted concept mapping group had a significant positive effect problem solving skill.

Key words: Concept mapping, learning strategy, problem solving skills, troubleshooting, TLE, Thailand

INTRODUCTION

Today's working conditions of automotive service technicians have required strategy-based diagnosis in the profiles of competence which basically stemmed from the rapid change and transformation in the nature of automotive technology. For automotive service technicians to adapt in this competitive world, they need to integrated electronic systems and complex computers regulate vehicles and their performance. In addition, technological changes along with the problem-solving skills in the workplace have made cognitive skills more important than ever before situations (Anderson, 1980; Davidson and Sternberg, 1988; Hall *et al.*, 1995; Hernandez-Serrano and Jonassen, 2003; Jonassen, 1997, 2000, 2004; Jonassen and Hernandez-Serrano, 2002; Jonassen and Hung, 2006; Kolodner, 1993; Renkl and Atkinson, 2003; Schaafstal and Schraagen, 2000; Sinnott, 1989; Sudsomboon and Anmanatarkul, 2009). As a result, the office of the National Education Commission (NEC, 2006) stressed the importance of workforce competencies in the areas of technical and vocational education and training. In order to reinforce this report, students must continually adapt to changing technology and cognitive skills as knowledge of procedures and systems become increasingly sophisticated. Lack of procedural knowledge has regarded higher order thinking competencies as complementary for productive workplaces including problem solving, reasoning and decision making. Moreover, without the appropriate type of learning, there can emerge across a range of hands-on and cognitive skills and ability to apply knowledge in a workplace situation (Schaafstal *et al.*, 2000). In this respect, a key learning strategy in automotive troubleshooting tasks is the development of procedural knowledge where novice troubleshooters understand multiple alternative solutions and apply them effectively to diagnose faulty systems and repair, corrective action to manipulate the problem-solving procedures in order to return the systems to their normal situations. It is crucial for instructor candidates to have these higher order thinking and problem-solving skills along with the ability to operate and work effectively. Thus, the computer-assisted concept mapping learning strategy employed in the Troubleshooting Learning Environment (TLE) with ill-structured problem-solving learning outcomes by working with individuals peace to make effective thought decisions, take the initiative and solve problems (Jonassen, 1997; Jonassen and Hernandez-Serrano, 2002).

Corresponding Author: Weerayute Sudsomboon, Learning Innovation in Technology Program, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, 126 Pracha-UTIS Road, Bangmod, Toong-Kru, 10140 Bangkok, Thailand

Computer Assisted-Concept Mapping (CA-CM): Concept mapping is a strategy of graphically representing concepts and their interrelations. Concept maps are designed by a linear fashion that depicts the knowledge structure in proportional statements and the relationships among the concepts in a map (Chularut and De Backer, 2004; Koul *et al*., 2005; Novak, 1998; Novak and Gowin, 1984). Based on Ausubel's assimilation theory of cognitive learning (Ausubel *et al*., 1978), concept maps visualize the hierarchy and relationships of concepts. Through the knowledge representing of a concept map, meaningful learning can be assisted (Novak, 1990). Heinze-Fry and Novak (1990) suggested that meaningful learning is facilitated because concepts are seen not as isolated entities but as existing in a network of relationships. Hence, concept maps can assist the preparation of organize new and existing knowledge about a topic by relating concepts in a way that promotes successive and progressive in the learning outcomes (Novak, 1995; Novak *et al*., 2000). Because of the utility of concept maps in the workforce education and development and the learning innovation in technology, self-controlled learning pace and higher expectations of computer-assisted concept mapping (Hilbert and Renkl, 2009; Liu *et al*., 2010), researchers developed a Computer Assisted-concept Mapping (CA-CM) for instruction and assessment of novice troubleshooters. They can use CA-CM to create concept maps relative to diagnose faulty systems and repair in a troubleshooting learning environment. A novice can construct the concept maps based on the Novak scoring protocol evaluation system within CA-CM on problem-solving skills to achievement against the expert's concept map (a criterion concept map) on the same automotive troubleshooting task to produce a score and relevant feedback. Because troubleshooters have the ability to evaluate their concept maps, they can use CA-CM iteratively to improve their score and understanding the topic by themselves.

Concept mapping automotive troubleshooting tasks strategy: Concept mapping is most widely applied in science technology (Novak and Gowin, 1984; Roth and Roychoudhury, 1992) aimed to monitor and explore cognitive scientific conceptual change processes. The faced a problem that the paper and pencil tests were unable to measure cognitive understanding validly. Thus, they prompted to create a prototype of concept map as an assessment tool that promote to explicitly express their varying degrees of understanding and track their conceptual changes over time. Novak's concept map stressed the essential role of prior knowledge in being able to learn new concepts (Novak, 1990). While adopting concept mapping in automotive troubleshooting task, troubleshooters need to confirm the concept of a topic creating from its diagnose faulty systems and repair, to identify and procedures and to arrange the concepts around the expert's concept map.

Then troubleshooters must link and align the relationship of some concepts and construct process is top-down automotive troubleshooting task. In addition when mapping troubleshooters apply individual prior knowledge to organize the new solution so that the troubleshooters can develop a new knowledge actively (Ruddell and Boyle, 1989). The troubleshooters can also review the relationships between concepts. This process is promoting the utilizing prior knowledge to construct meaning has the positive effect of a top-down automotive troubleshooting task model.

Likewise, the mapping process integrates the bottom-up and top-down comprehension models (Huang, 2005; Kintsch and van Dijk, 1978). Two approaches to concept mapping are already used in workplace;one is the learner-constructed concept map; the other one is the expert-constructed concept map. For the learner-constructed concept map, instructors ask learners to construct concept maps themselves after explaining and demonstrating concept map to them. The expert-constructed concept map is another method of teaching and learning strategies. This study differs the former expert-constructed concept map because used to train troubleshooters in a comprehension of the problem-solving skills and to save instructors time in teaching (Hall, 1988; Jonassen *et al*., 1993). In case, research of Chularut and De Backer (2004) indicated that students with low proficiency benefited more from concept mapping strategies. They also found that the concept mapping group showed significantly greater gains from pre-test to post-test students, learning different concept mapping strategies. Moreover, Haugwitz *et al*. (2010), he concept mapping strategy was found to be advantageous only for students whose cognitive ability was below the median for the sample and who were placed in groups with other students having low cognitive ability. Thus, research results on the effects of concept mapping on automotive troubleshooting ability in specific and for troubleshooters gained proficiency knowledge structure and problem solving skills.

CA-CM in troubleshooting learning environment:. There are extensive and promoting conceptions of the troubleshooting process as the faulty component is finding in a device and repairing or replacing it (Perez, 1991). In order to research a Troubleshooting Learning Environment (TLE) was developing by according to Johnson *et al*. (1993), troubleshooting consists of four subtasks:

- Problem space construction
- Problem space reduction
- Hypotheses generation/testing (fault isolation/ diagnosis process)
- Solutions generation/verification

This study is integrating computer assisted learning with concept mapping in a troubleshooting learning environment leads learners to create concept maps actively to achieve positive effects in automotive troubleshooting tasks. Computerized concept mapping is easily succeeded and it attempt learners create concept maps quickly and accuracy.

Thus, computerized concept maps strategies are more helpful in organizing information and promoting comprehension than traditional learning strategies. Computers are linking both instructors and learners interactive as well (Anderson-Inman and Zeitz, 1993; Novak and Gowin, 1984). In other words, computers can track and record learners' concept-constructing processes, analyze their thinking patterns and re-solve test results (Forgen and Hargrave, 1999; Shin *et al*., 2000, 2003).

The IHMC CmapTools have potentially been made available; consequently, it use to employ in this study. Troubleshooters can download it from the internet. Messerotti (2010) undertook the IHMC CmapTools software in research and education which its application for the high-level development of multi-level concept maps in the framework of Space meteorology. In Messerotti's study, they are suitable to be published on the web; the coded knowledge can be exploited for educational purposes by the students and the public as the level of information. The study provided evidence that CmapTools software can be naturally organized among linked concept maps in progressively increasing complexity level for high-level knowledge representation in research and education.

The present investigation: The aim of the study was to investigate the effectiveness of computer assisted concept mapping as a strategy for learning in automotive troubleshooting tasks. Specifically, this study compared a computer assisted concept mapping condition and a traditional concept mapping learning condition.

The key questions raised were: Do the knowledge acquisition scores the Computer Assisted-concept Mapping (CA-CM) group increase more significantly than the scores of the Service Manual Concept Mapping (SM-CM) group? and Do the concept mapping scores of the CA-CM group increase more significantly than the scores of the SM-CM group?

MATERIALS AND METHODS

Design: This study took place during the 2nd of a 5 days session at the training centre of Mitsubishi motors (Thailand) in February, 2010. A Quasi-experimental design was chosen, involving non-random assignment into two groups and this used a non-equivalent pr-test to post-test control group design with a Troubleshooting Learning Environment (TLE). Both knowledge acquisition and concept maps were conducted to consider the effects of scores.

Prompted learning strategy: The study can be divided into a computer assisted-concept mapping group and a service manual (paper-pencil) study plus discussion group. Prior to the experiment, the concept mapping group and the service manual study plus discussion group completed pre-tests. This involved studying the 5 tasks on automotive troubleshooting that are assessed with concept maps. At the end of the experiment, all of the troubleshooters completed post-tests.

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

Participants: Total 50 practitioners attending the training centre of Mitsubishi motors (Thailand) volunteered to participate in this study. Participants ranged in age from 20-46 years and included 50 males. All of the participants were Mitsubishi automotive service technicians.

Procedure

Treatment procedures: Class activities were implemented with the 1st day. Troubleshooters were informed about Mitsubishi automotive troubleshooting tasks; problem space construction, problem space reduction, hypotheses generation/testing (fault isolation/diagnosis process) and solutions generation/verification. The CA-CM group was exposed to create maps in 5 tasks ill-structured problem scenarios which developed through the following steps (Johnson *et al*., 1993):

- Use many observation in a sequence of simple decisions
- Use general search procedures that are not dependent on actual system or fault
- Search to find faulty component
- Search through systems to identify appropriate sub-system, state or component

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

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

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

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

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

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

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

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

- Relationships: One point for each valid proposition
- Hierarchy: Five points for each level of hierarchy
- Cross-links: Ten points for each valid cross link
- General to specific example: 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 5 tasks on automotive problem space that are assessed on computer-assisted concept maps were explained to the troubleshooters in the experiment group (Table 1).

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.

Problem space construction: Researchers focused on the constructing problem space are the 1st step in solving problems (Newell and Simon, 1972). Problem solving must begin with the conversion of the problem statement into an internal representation (Reimann and Chi, 1989). Therefore, the problem space of any troubleshooting problem is the mental model of the task environment that the troubleshooter constructs on CA-CM. For instance, the electronic fuel injection control systems are represented as wiring diagrams, exploded views of mechanical and electronic systems and flowcharts of diagnostic procedures. External problem space representations guide troubleshooters construct internal representations of the system. Later, researchers demonstrated a multi-layered external problem representation for guiding learners that includes topographic description of the system components, functional descriptions of the system flow, normal behaviors of the system components, symptoms or behaviors the system exhibit when operating correctly and faultily and representations of strategic decisions required during troubleshooting.

Identify fault symptoms: Researchers trained troubleshooters use strategic knowledge about which procedures to perform in order to identify discrepancies. Recognizing symptoms of faulty components is also aided by experience. The likelihood of symptoms becoming apparent is a function of historical knowledge.

Table 1: Phases in the study

Phases	Experimental group	Control group
Pre-testing		
Day 1	Basic information and MATT test	Basic information and MATT test
Experiment		
Day 2	CA-CM Diesel engine diagnosis	SM-CM Diesel engine diagnosis
Day 2	CA-CM MPI engine diagnosis	SM-CM MPI engine diagnosis
Day 3	CA-CM Common rail diesel direct injection system diagnosis	SM-CM Common rail diesel direct injection system diagnosis
Day 3	CA-CM Steering system diagnosis	SM-CM Steering system diagnosis
Day 4	CA-CM Automatic transmission diagnosis	SM-CM Automatic transmission diagnosis
Post-testing		
Day 5	MATT test	MATT test

Diagnose fault (s): After constructing a problem space, the troubleshooter begins the diagnosis process by examining the faulty system and comparing the system states to similar problems those themselves solved. Experience troubleshooter can valid proposition on CA-CM. They created the CA-CM categories; relationship, hierarchy, cross-links and general to specific example. Experienced troubleshooters categorize problems based on prior experiences. Throughout the process of hypothesis generation and testing cycles (Johnson *et al*., 1995), the troubleshooters attempt to further narrow the problem space and isolate potential faults. Johnson (1989) explained that these potential hypotheses are generated to provide possible explanations for the causes of the system fault. Researchers classified hypotheses while troubleshooters create concept maps into 4 levels:

System: The hypotheses conjecture the fault at the system level but do not reduce the problem space beyond the entire equipment or complete system.

Sub-system: The hypotheses conjecture the fault at the subsystem level and reduce the problem space to a discrete sub-system within the complete system.

Device: The hypotheses conjecture the fault at the device level and reduce the problem space to a limited number of components within a sub-system.

Component: The most specific type of hypotheses that conjecture the fault at the component level and result in the identification of a single component as the potential fault cause.

Generate and verify solutions: Researcher suggested the troubleshooter needs to generate one or more solutions for repairing the system based on the results of tests. As with diagnosis, skilled troubleshooters rely 1st on their experiences. They must know that certain solutions are quicker, easier, cheaper or more reliable. They must select the most plausible solution from the set of solutions generated (Johnson *et al*., 1993) and determine which best meets all the constraints (e.g., effectiveness, efficiency, system-specifies or economic consideration).

Phases in the study: All 5 tasks are based on Mitsubishi automotive technology that has the following; diesel engine diagnosis; Multi-port Injection (MPI) engine diagnosis; common-rail diesel direct injection system diagnosis; steering system diagnosis and automatic transmission system diagnosis.

Data collection

Intervention problems: Troubleshooters were given a hand-out with 5 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 5 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.

Assessments: The pre- and post-test had assessments of 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 procedural knowledge items assessed troubleshooters' ability to solve automotive tasks. At post-test, troubleshooters completed the full assessment in the day 5. At pre-test, troubleshooters completed a subset of the overall assessment all the knowledge acquisition items. 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 5 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 0.89.

For the concept mapping, the practitioners drew their concept maps using computer-assisted techniques. The concept maps were evaluated on a 100 point scale. The session began with a 30 min 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.

Data analysis: Descriptive statistics were used to illustrate the CA-CM and the SM-CM of the participants for each measurement. Two-way mixed design Analyzes of Variance (ANOVA) were conducted to see the effects of both scores. At the inception of interpreting significance of the results, the probability value was yielded at 0.05.

RESULTS

Do the knowledge acquisition scores the Computer Assisted-concept Mapping (CA-CM) group increase more significantly than the scores of the Service Manual- concept Mapping (SM-CM) group? In order to consider whether the pre- and post-test scores of the

Table 2: Descriptive statistics regarding pre- and post-test knowledge acquisition scores

	Pre-test			Post-test		
Groups	N	M	SD	N	M	SD
CA-CM	25	22.94	3.15	25	38.68	2.74
SM-CM	25	23.16	3.07	25	35.93	3.03

Table 3: Summary of mixed design ANOVA conducted with pre- and post-test knowledge acquisition score

Source	SS	df	MS	F	p-values
Between groups	369.832	49	-	-	-
Group (CA-CM/ SM-CM)	34.065	1	34.065	3.184	0.042
Error	335.767	48	6.851		
Within groups	2987.662	50	-	-	-
Measure (pre- and post-test)	2643.519	1	2643.519	246.108	0.000
Group* measure	38.740	1	38.740	4.257	0.083
Error	428.377	48	12.936		
Total	3146.927	99	-	-	-

CA-CM increased more significantly than the scores of the SM-CM group, prior knowledge and post-test scores of both groups were calculated first as shown in Table 2.

The CA-CM group's pre-test (M = 22.94) increased to (M = 38.68) in the post-test whereas the SM-CM group's pre-test (M = 23.16) increased to (M = 35.93) in the post-test. That is both groups had highe scores in the post-test. However to determine which group's progress was better two-way mixed design ANOVA was used which is shown in Table 3.

The progress levels of the CA-CM and the SM-CM did not follow a different pattern through measurement ($F_{(1.48)}$ = 4.257, p>0.05). That is CA-CM did not have a different effect than SM-CM activities in terms of knowledge acquisition. Even though both groups had significantly higher scores in the post-test ($F_{(1.48)}$ = 2643.519, p<0.001), it was not possible to maintain that one of the group outperformed the other. However, the probability was close to significance ($F_{(1.48)}$ = 3.184, p = 0.042) on behalf of the CA-CM group which should be revised in further experiments.

Do the concept mapping scores of the CA-CM group increase more significantly than the scores of the SM-CM group? In order to consider whether the concept mapping scores of the CA-CM group increase more significantly than the scores of the SM-CM group, concept mapping scores were calculated as shown in Table 4. The CA-CM group's pre-test (M = 70.85) increased to (M = 83.27) in the post-test whereas the SM-CM group's pre-test (M = 68.39) increased to (M = 75.12) in the post-test. That is both groups had higher scores in the post-test. However to determine which group's progress was better, two-way mixed design ANOVA was used which is shown in Table 5.

Table 4: Descriptive statistics regarding pre- and post-test concept mapping scores

	Pre-test			Post-test		
Groups	N	M	SD	N	M	SD
CA-CM	25	70.85	6.67	25	83.27	7.65
SM-CM	25	68.39	6.88	25	75.12	8.90

Table 5: Summary of mixed design ANOVA conducted with pre- and post-test concept mapping scores

Source	SS	df	MS	F	p-values
Between groups	3122.410	49	-	-	-
Group (CA-CM/ SM-CM)	134.210	1	134.210	1.650	0.141
Error	2988.200	48	6.851	-	-
Within groups	1907.027	50	-	-	-
Measure (pre- and post-test)	868.325	1	868.325	29.236	0.000
Group* measure	124.653	1	124.653	3.849	0.028
Error	1026.585	48	27.392	-	-
Total	4367.556	99	-	-	-

The progress levels of the CA-CM and the SM-CM did not follow a different pattern through measurement ($F_{(1.48)}$ = 3.849, p>0.05). In this regard, this study could be recommended that exposing troubleshooters to the CA-CM and the SM-CM activities had different effects on concept mapping scores. Moreover, the CA-CM group had higher gains in terms of concept mapping than the SM-CM group even though, they were equal at the inception.

DISCUSSION

This study conducted in the troubleshooting learning environment revealed that the CA-CM group and the SM-CM group did not differ in terms of knowledge acquisition. Finding were somewhat in line with the Cline *et al*. (2010) study, a rule-based system for automatically evaluating student concept maps found that after students use the drawing facility of the Concept Mapping Tool (CMT) to construct individual concept maps for a particular topic that was presented in a course. Students are given immediate feedback on how to improve their concept maps and they can use CMT iteratively to improve their understanding of the topic at hand.

Although, there is that concept maps used in pedagogy are most useful when they are increased knowledge acquisition skills or scored (Edmonson, 2000; Ruiz-Primo *et al*., 2001). This is true whether concept maps are constructed using paper-pencil or electronically on a computer. Therefore, computer-assisted concept mapping strategy leads troubleshooters to construct concept maps actively to achieve positive effects in learning. Computerized concept mapping strategy is easily corrected and it helps to construct concept maps quickly. The use of computerised mapping also makes instructors and learners interactive (Anderson-Inman and Zeitz, 1993; Novak and Gowin, 1984). According to Shin, Deno, Robinson and Marston, computers can track and record learners' concept-constructing processes, analyze their thinking patterns and resolve test results (Forgen and Hargrave, 1999). The difference between the CA-CM and the SM-CM group may stem from the cognitive ability of troubleshooters as well. Even though, the cognitive ability affected that summarizing is an information source. They created the effectively concept maps for obtaining cognitive and metacognitive learning (Anderson and Thiede, 2008). According to van Dijk and Kintsch's theory by analyzing sentences into propositions and deleting, linking, generalizing and inferring propositions, readers construct a hierarchy of propositions that encompasses a detailed microstructural model of the source text and a condensed macrostructural model derived from it. Hence, constructing highly achievement troubleshooters are enabled by their cognitive abilities and guided by their prior knowledge of content knowledge acquisition and problem-solving skills.

In the SM-CM strategy, only relationships between concepts can be established on the maps. It was observed that the concept mapping prepared by using SM-CM were very complicated. According to the results of the Mitsubishi Automotive Technology Test (MATT), a significant difference was observed between the pre- and post-test scores of the experiment group. It can be stated that the concept maps prepared using CA-CM were the effectiveness in concurrence of this study. The difference between the pre- and post-test results was not significant in the control group. In fact, the concept maps prepared using the SM-CM strategy was lacking. In order to accomplishment, the troubleshooters compile a knowledge structure which indicates interrelationships among concepts that represent meaning in specific domains. The expertise arranges concepts (perceived regularities designated by a label) and hierarchical (Ruiz-Primo *et al*., 2001).

In additional, Jonassen and Hung (2006) described that constructing problem space is the 1st step in solving problems (Newell and Simon, 1972). Researchers identified that the mental model of the task environment is the problem space of any troubleshooting tasks. As a result, recognizing symptoms of faulty components is also aided by experience (Jonassen and Hernandez-Serrano, 2002; Kolodner, 1993) while the troubleshooter begins the diagnosis process by examining the faulty system and comparing the system states to similar problems. For instance, Johnson (1989) explained that the process of hypothesis generation and testing, the troubleshooters attempt to further narrow the problem space and isolate the potential faults. Computer can be represented the concepts progress from the most general in the centre to the most specific on the right and the left with the digital technique. Service manual can not be effectively in the concepts progress because they had loss in time for search the data and information. The advantage of computer assisted proposed that concepts are linked for meaning by linking-words such as to, from, have, are, like, produces, including, resulting in and acts on. Cross linkages indicate relationships among concepts. As an instructional technique, concept mapping involves students in their own learning, encourages them 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 (Markham *et al*., 1994).

Such a strategy which requires high level problem solving skills can not only stimulate the practitioners' meta-cognition perception but also helps the practitioners to use self-monitoring and helps them with memorising and drawing out their knowledge during the process of mapping (Ausubel, 1968; Beyerbach and Smith, 1990; Chen and Chang, 1997; Freeman and Jessup, 2004; Horton *et al*., 1993; Jonassen *et al*., 1998; Novak, 1990; Novak and Gowin, 1984).

As an assessment technique, concept mapping is integrated with instruction to continue progress in automotive training. Concept mapping can measure troubleshooters' progress and achievement and promote self-reflection by providing feedback on training progress (Koul *et al*., 2005). The trainer can assess concept maps by examining them for a number of concepts, quality of linkages, appropriateness of the hierarchical organization and richness of cross linkages.

CONCLUSION

The study suggested that computer-assisted concept mapping strategy can promote the most plausible solution from the set of solutions generated and examine the competency on automotive problem-solving skills learning course (e.g., effectiveness, efficiency, system-requirements and life-long learning). Based on the results, the troubleshooter accepts the selected solution. Although, this research showed that a concept map construction task can be used effectively to accommodate the requirements of domain and context-specific knowledge structures. The concept maps can display linked concepts and the underlying notes make it easier to identify the knowledge representation process of their map. Researchers are continually searching for innovative and effective tools to assist practitioners in their cognitive task analysis of training in order to integrate technology and the research identified deficiencies in their subject knowledge.

IMPLICATIONS

The troubleshooter needed to generate one or more solutions for repairing the system based on the results of tests. In many troubleshooting circumstances that is the preferred alternative solution because it requires the least time. As with diagnosis, cognitive troubleshooters rely first on their experience.

Jonassen and Hung (2006) argued that troubleshooters know that certain solutions are quicker, easier, cheaper or more reliable. In automotive systems, they are represented as wiring diagrams, exploded views of mechanical systems and flowcharts of diagnostic procedures. External problem space representations help novice troubleshooters construct internal representations of the system. They need to construct fewer problem spaces of those complex systems. The important issues are based on the normal and fault states for system components represented in the problem space, troubleshooters use strategic knowledge about which procedures to perform in order to identify discrepancies.

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