The Effects of Concept Mapping and Case-based Learning Instructional Approaches on Automotive Problem Solving Skill

Weerayute Sudsomboon, Ph.D.

Author Note

Correspondence concerning this paper should be addressed to Weerayute Sudsomboon, Department of Mechanical Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, 126 Prachautis Road, Bangmod, Toongkru, Bangkok, Thailand, 10400, Phone: (662) 470-8526, Fax: (662) 470-8527, Email: weerayute.sud@kmutt.ac.th

Abstract

The purpose of this research was to investigate the effects of two instructional approaches (concept mapping versus case-based learning) on learners' problem solving skills. To examine differences between the two groups on the concept mapping achievement test, the case-based learning achievement test, and the transfer test, the researcher employed a two-way (instructional × level of prior knowledge) multivariate analysis of variance (MANOVA). To survey the learner attitudes, researcher employed a mean score. Data were collected from 48 undergraduate mechanical technology education students at King Mongkut's University of Technology Thonburi. Results revealed that the concept mapping group performed significantly better than the case-based learning on a problem-solving skill test and a transfer test. The finding of the concept mapping is realized through a case study in a workplace. The implications of the approach for supporting automotive problem solving skill validity, inclusion of demand-driven, and theory-driven experimental are discussed.

Keywords: Automotive Technology Education, Concept Mapping, Learning Strategy, Problem Solving Skill

The Effects of a Concept Mapping and Case-based Learning Instructional Approaches on Automotive Problem Solving Skill

1. Epistemology of the automotive problem-solving skills: concept mapping vs. case-based learning instructional approaches

Today's automobiles are as much electronics as they are mechanical. Computers now monitor and control all major systems of a modern automobile. In fact, automobiles are as much electronic as they are mechatronics. It is difficult to perform on almost any electronic control system without having cognition occurs in two contexts, knowledge representation and metacognition (Haugwitz, Nesbit, & Sandmann, 2010; Jonassen, 1997, 2000, 2004; Jonassen & Hung, 2006; Kolodner, 1993; NATEF, 2008). This framework provides a "classification of levels" of intellectual behavior important in learning environment for practicing learning approaches in which learners can make their "existing cognitive structures" (Bloom, 1956; Pohl, 2000; Novak & Gowin, 1984). Thus, a research focus nowadays lies on modern instructional strategies are often individual learner think aloud more thoroughly. This makes it important for students' to fully solving the problem how automotive computer systems diagnosis.

In a complex learning environment, the epistemological foundation for most education is *absolute knowing* into problem-solving skills (Perez, 1991; Phye, 2001). Learners believe that knowledge and real world situation are certain and should be obtained from authorizes. On the other hand, automotive problem-solving skills requires *transitional knowing* (transfer) is partially certain and requires understanding using logic, knowledge and experience, and *contextual knowing* (time and attitudes) is based on evidence in context (Renkl, & Atkinson, 2007; O'Donnell, Dansereau, & Hall, 2002; Schaafstal, & Schraagen, 1993).

For instance, the troubleshooting malfunctions of an electronic fuel injection control system, the difficulty of the learning approaches stems complexity of integrating knowledge, skills, and attitudes, coordinating qualitatively different constituent skills, and using case-based processes in solving a problem (Bloom, 1956; Jonassen & Hung, 2006; Sudsomboon & Anmanatarkul, 2009; Sudsomboon, 2010). Modern instructional strategy in automotive technology education has become an intensive course in industrial education and technology area. One of the outcomes expectations that have received empirical attention is problem-solving skills.

Hence, problem solving is an instructional method encourages students to perform for new solutions to relevant problems using available knowledge and resources (Jonassen 2000, 2004; Jonassen & Hung, 2006; Perez, 1991; Plotnick, 1997; Phye, 2001; Uribe, Klein, & Sullivan, 2003). Recently, the researches in automotive technology education have been criticized as being relatively ineffective in promoting knowledge representation of learning, particularly in teaching performance/procedural knowledge. Procedural knowledge is specific to the system and the tools used to solve the automotive computer systems. Therefore, its application is limited to that particular content or system diagnosis regarding concept mapping and case-based learning (Jonassen, 2000; Kolodner, 1993; Schaafstal and Schraagen, 1993).

2. Theoretical framework

2.1 Learning with the logical

One of the major hurdles that must be addressed by institutions teaching automotive problem-solving skills is that well-defined problems used in instructional setting are often significantly different than the ill-defined problems encountered in the real world (Jonassen, 2000). Because the problems used in traditional instruction design to be taken out of context and provided with artificial structure (Jonassen & Hernandez-Serrano, 2002). Therefore, many traditional automotive technology education programs do not adequately prepare students for effective social demand (Jonassen & Hung, 2006; Shin, Jonassen, & McGee, 2003; Sudsomboon & Anmanatarkul, 2009; Sudsomboon, 2010).

Often provided with problem-solving skills that have accuracy, cognitive skills, alternated solution, students learn to follow a current situation of symptoms and faulty diagnosis to achieve solution. Thus, instead of learning the techniques for effectively solving problems, students learning with these “knowledge structure” problems learn to follow alternated solution steps, rather than actively trying to solve the presenting problems (Hilbert & Renkl, 2009).

2.2 Concept mapping

In addition, several researchers have suggested that the concept mapping is meaningful learning involve the assimilation of new concepts and propositions into existing cognitive structures (Novak as cited in Plotnick, 1997). Concept mapping is a strategy to helps learners organize information through visual aids while a concept map is a diagram showing the relationships among concepts. Concept mapping techniques are interpreted as representative of students’ knowledge structures (Mintzes, Wandersee, & Novak, 1997; Novak & Godwin, 1984; Yin et al., 2005). Concept maps require users to identify, graphically display, and link key concepts by organizing and analyzing information. They make the structure of knowledge visually explicit and conceptually coherent. By definitions, knowledge representation in automotive computer systems consists of many knowledge states, each of which must be performed in functional domain knowledge, system/device knowledge, performance/procedural knowledge, strategic knowledge, and experiential knowledge.

O'Donnell, Dansereau, and Hall (2002) described that effectively learning to solve problem is a key factor in producing favorable outcomes when concept mapping is employed. To improve learners' solving the problem ability, effective instructional strategies and innovative tools are being widely considered. Those strategies involve *procedural processing*, such as decision making, problem-solving, and reasoning (Jonassen, 1997; Novak, 1990), promotes the acquisition of knowledge and exchange of information. While adopting concept mapping in automotive problem solving, learner need to confirm the concept of a problem diagnosis, working from knowledge states from its capacities to solve, to causal reasoning, and analytical reasoning, and to arrange the concept as a result of constantly checking faulty symptoms. These benefits of concept mapping have been widely recognized.

2.3 Case-based learning

Additionally, Case-based learning (CBL) is a well-established instructional method, when practicing CBL, researcher logic two instructionally challenging issues need always careful interventions (Feltovich, Spiro, Coulson, & Feltovich, 1996):

(1) First, how to help students avoid misconceptions by not oversimplifying the material. Students need to work through several cases to develop deeper domain-specific knowledge (Kolodner, 1993, p. 131).

(2) Second, the "knowledge transfer problem", or how to support students apply their knowledge to novel problem situations, which many significantly differ from those encountered in the instructional setting (Kolodner, 1993, p. 138).

Indeed, the problem representation processes in ill-structured problem-solving requires that solvers recall and reflect on a large amount of related information from memory (Voss & Post, 1988). In case, researcher argues that their reasoning and argumentation is to be successfully transferred then students need to be supported in their ability to recall relevant cases for reasoning in novel problem-solving situation. It has fit into design in this study.

3. Present Study

In the current study, students in a mechanical technology program were provided with two instructional methods and encouraged to use it to solve problems of NISSAN electronic concentrated engine control system (ECCS) diagnosis encountered. The primary purposes of this study was to examine whether such transfer would occur when the two instructional approaches was used to teach learners on problem-solving skills.

The hypothesis of this study was that a concept mapping approach would yield higher concept mapping achievement and transfer test than a case-based reasoning approach. The effects of both approaches on concept mapping, the time spent on tests were also measured. The possible interactions between levels of learner prior knowledge and the two instructional approaches on these additional variables were also determined.

4. Method

4.1 Participants

Participants were 48 undergraduate mechanical technology education students at King Mongkut's University of Technology (KMUTT) in 2 days in February 2011 (*M* age = 20.24 years; 91 % male and 9% female) enrolled in four sections of fault diagnosis modules: 1) fuel delivery system, 2) air induction system, 3) electronic control systems, and 4) ignition system. The learners, all of whom were pre-service teachers in the compulsory course, were learnt how to solve various NISSAN electronic concentrated engine control system (ECCS) diagnosis.

Learner in two units were taught by the same instructor. They involved in the study during their regularly scheduled workplaces. Participants in the experiment was volunteered a course requirement.

4.2 Independent variables

For both instructional conditions, instruction consisted of two 120-min modules. The manner in which the first session of each unit was conducted was the same across both conditions. Namely, the instructor began each module by concept mapping (a) problem representation; (b) solution formulation; (c) justification; and (d) monitoring/evaluation where those concepts and skills had been used. The second session of the unit, which varied between the conditions, then began.

Concept mapping approach. In the concept mapping condition, the instruction described and demonstrated 14 constituent skills involving in preparing a service manual: 5 fairly basic skills, 6 intermediately skills, which were taught during the first module, and 4 advanced skills, which were taught during the second unit. Thus, 14 demonstrations were presented to the learners. The first study session began with a 120-min introduction and application to the concept mapping strategy.

Learners received service manual and handout materials that included an introduction to knowledge structure with concept mapping, a list of characteristics of concept maps, methodology for creating concept maps, and examples of well-constructed and poorly constructed concept maps. Concept maps were conducting the following procedure:

1. Posses the NISSAN (ECCS) troubleshooting task in each module was to select major concept to be included in the map.

2. Rank or organize the lists of concepts from the possible causes and specific.

3. Cluster the concepts according to Novak scoring protocol: hierarchical structure, concept-links, cross-links, and examples.

4. Arrange the concepts in a configuration to depict relationships among the concepts.

5. Concept-links related with lines and label each line with a problem-solving skill.

In four sections subsequent 120-min unit learners used the concept mapping strategy. Each session included the articulate sequence of situations: (a) concept maps from the previous session were returned to learners with feedback regarding correctly and accuracy, (b) learners provided with a new troubleshooting task and encouraged to create concept maps of the problem-solving performance while researcher monitored learner progress and provided feedback, and (c) the newly created concept maps were collected for subsequent feedback.

Case-based learning approach. CBL studied the same two unit learners in the same sequence as the concept mapping group; however, these sessions were conducted using a conventional students commonly encountered at the KMUTT. That is, students were identified with the case of the day and a handout containing definitions of faulty symptom from the service manual, and were encouraged to perform the NISSAN Consult III Scan Tool individually for 30 min, identifying and analyzing the faulty symptom 30 min, problem-solving processes skill individually for 30 min, asking the instructor for assistant as needed. At the conclusion of the case-based learning, the instructor led a 30-min whole-group discussion of the outcomes and implications.

In addition, *procedural information* was provided to learners whenever they needed it to perform particular constituent problem-solving skills. For example, the first time a learner needed to prior problem-solving procedure names camshaft position sensor fault symptom, he or she was not understood the diagnoses process and articulated the similar components for performing this case.

Level of leaner prior knowledge. The levels of learner prior knowledge were examined by using the data obtained from a prior-knowledge test (pre-test). The pre-test measured whether or not a participant could already perform problem-solving skills (e.g., a knowledge representation) that were focus of the instruction. On the pre-test item an incomplete faulty symptom was presented in which the average and total was not appeared, and learners were required to create a concept mapping using the NISSAN Consult III Scan Tool by performing a series of tasks (e.g., diagnostic trouble codes, current data, actuation test, graph view, and so on), involving a total of 10 basic, intermediately and advanced skills.. A maximum of 10 points could be earned on the pre-test, one for each of the 10 skills a learner performed correctly.

Based on data from previous research, if a participant was able to perform at least five intermediate skills (e.g., trial and error, exhaustive, typographic, spit-half, functional/discrepancy detection) and one advanced skill (recognizing symptom, faulty diagnosis, create a flowchart). The pre-test results revealed those 23 higher-prior knowledge learners and 25 lower-prior knowledge learners. The mean pre-test scores for both of these groups of learners were relatively low; the mean score for the higher-prior knowledge group was 64% (M = 17.6, SD = 0.48), while the mean score for the lower-prior knowledge group was 48% (M = 13.4, SD = 0.82).

4.3 Dependent variables

Problem solving skill. Learner problem-solving skill of NISSAN electronic concentrated engine control system (ECCS) diagnosis taught during the instructional unit was measured by two *achievement tests*: a concept mapping achievement test and a case-based learning achievement test. The concept mapping achievement test required learners to perform 10 separate concept map tasks. The case-based learning achievement test required learners to prepare a service manual that incorporated a given set of features. On both tests, some of the features the learners created could sophisticatedly be scored as correct or incorrect within data processing. A scoring rubric was used to consider the adequate of a particular feature on a three-point or five-point scale. Learners could earn a maximum of 67 points on the concept mapping test and 53 points on the case-based learning test

Transfer. Ability to transfer the problem-solving skills they had been employed was measured by a transfer set that presented learners with a set of knowledge representation and required them to use NISSAN Consult III to diagnose a faulty symptom incorporated a variety of features. A scoring rubric was used to score particular features on either a three-point or five-point scale. Learners could earn a maximum of 68.1 points on the transfer test.

The analysis yielded Kappa coefficients of 0.82, 0.86, 0.78, and 0.91, respectively. By convention, k = 0.40-0.59 is moderate interrater reliability, 0.60-0.79 is substantial, and 0.80 or higher outstanding (Landis and Koch 1977). The Cronbach's alpha and resulted in reliability indices of 0.84, 0.80, 0.92, and 0.86, respectively.

Time on tests. The time each learner took to complete each test was measured by setting the learners to solve their start and end times of the two achievement tests on the transfer test.

Learner attitudes. The attitude of the learners toward the instruction was measured by a 20-item Likert-type questionnaire adapted from Thai Educational Technology Motivational Survey. Learners responded to these statements by using a five-point Likert scale (1 = not satisfaction, 5 = very satisfaction). The overall survey used in this study had a reliability of 0.90, as measured by Cronbach's alpha.

4.4 Procedure

Two 120-min units were presented to each treatment group. In both treatment conditions both modules were presented on the same day, 2 days after the pre-test administered. Two days after the two lessons were presented to them, the learners were asked to complete the attitude survey and then were asked to compare the two achievement tests and transfer test.

4.5 Data analysis

To examine differences between the two groups on the concept mapping achievement test, the case-based learning achievement test, and the transfer test, the researcher employed a two-way (instructional × level of prior knowledge) multivariate analysis of variance (MANOVA). To survey the learner attitudes, researcher employed a mean score. The problem-solving performance depend on each test was compared across groups via three two-way ANOVAs, one of each of the three tests.

5. Results

5.1 Problem-solving Skill

Concept mapping achievement. As shown in Table1, both groups performed well on the 60-item concept mapping test. The mean score in the concept mapping condition was 88% (M = 52.3, SD = 5.85), whereas learners in the case-based learning condition had a mean score of 80% (M = 48.0, SD = 6.14). Although MANCOVA revealed a significant overall main effect for instructional approach on problem-solving skill and transfer, *Wilks Lambda* = 0.7, F (3, 42) = 7.61, $p < 0.021$, $\eta^2 = 0.53$, a follow up ANOVA, using a Berferroni adjusted alpha level of 0.021. This achievement test revealed that learners in the concept mapping condition scored significantly higher than the whole task achievement. The effect size estimate was *d* = 0.74, indicating a moderately strong effect.

Case-based learning achievement. As shown in Table1, both groups performed fairly on the 60-item whole-task achievement test. Learners in the concept mapping condition had a mean score of 81% (*M* = 48.8, *SD* = 3.64), whereas learners in the case-based learning condition had a mean score of 72% (*M* = 42.95, *SD* = 3.02). Although MANCOVA revealed a significant overall main effect for instructional approach on problem-solving skill and transfer, *Wilks Lambda* = 0.7, F (1, 44) = 7.23, $p < 0.05$, $\eta^2 = 0.36$, a follow up ANOVA, using a Berferroni adjusted alpha level of 0.021 , yielded no significant main effect for the instructional approaches on the whole task achievement.

Insert Table 1 about here

5.2 Transfer

On the transfer test, the mean score for the concept mapping group was 84% (*M* = 50.1, *SD* = 5.59), while the mean score for the case-based learning group was 76% (*M* = 45.5, *SD* = 6.93). A follow-up ANOVA, using a Berferroni adjusted alpha level of 0.017, revealed that the concept mapping group scored significantly higher than the whole-task group, F (1, 44) = 19.63, $p < 0.0021$, $\eta^2 = 0.13$. The effect size estimate was d = 0.96, indicating a large effect (Thalheimer & Cook, 2002).

5.3 Time on tests

The ANOVAs revealed that no main effect for instructional approach on time spent on the both achievement tests. In the whole-task test, learners with higher-prior knowledge spent significantly less time (*M* = 15.6 min, *SD* = 4.79) than learners with lower-prior knowledge (*M* =

21.2 min, $SD = 6.23$), $F(1, 44) = 8.02$, $p < 0.015$, $\eta^2 = 0.29$. There was no significant interaction between the two instructional approaches and the two levels of prior knowledge with regard to the time spent on any of the tests.

5.4 Learner Attitudes

The 20-item attitude survey consisted of four-subscales: attention, motivation, application, and satisfaction. As shown in Table 1, for each sub-scale, learners in each treatment group expressed highly positive attitudes in the range of 4.5-5.0 on a five point scale.

6. Discussion

This study was an effective means of promoting the problem-solving skills, time, and transfer of skills in automotive technology education. Learners in the concept mapping instructional condition performed significantly better than did their counterparts in the case-based learning condition. This finding revealed that these learners had more alternate solutions to solve the NISSAN electronic concentrated engine control system (ECCS) in concept mapping practice activities. Learners in the concept mapping group were also much better able than the case-based learning learner to transfer the problem-solving skills they found out: problem representation; solution formulation; justification; and monitoring/evaluation completely.

This result may be due to the fact that the concept mapping instructional approach carried out a think-aloud study to analyze the relations between cognitive processes during concept mapping as well as the characteristics of the concept maps the learners produced and learning outcomes. They were also characterized by employing very little planning and performing problem-solving strategies. However, the case-based learning group was also be due to the contexts in which the various tasks had to be performed, one of the lack for solving transfer of skill (Cline, Brewster, & Fell, 2010; Haugwitz, Nesbit, & Sandmann, 2010) .

Results between level of prior knowledge on problem-solving skill and transfer test revealed that no significant interactions. The pre-test did not assess learner ability to perform a number of the problem-solving skills taught in the second unit and assessed on the achievement and transfer tests, such as identify fault symptoms, hypothesis generation and testing, and generate and verify solutions. In addition, results revealed that survey attitudes in the concept mapping approach did not have more positive attitudes toward the instruction than learners in the case-based learning approach.

In contrast, prior knowledge proved the strongest scores affected that all aspect of achievement test, clearly stronger time on tests, and also than perform and feedback. In order to increase the effects of case-based learning, the processing of the solution formation and evaluation have to be intensified. Studies on example-based learning indicate that effective of self-explanation can be improved problem-solving skills prompting procedures (Renkl, 2007; Schworm & Renkl, 2007).

The time on tests revealed no differences between the two treatment groups in the amount of time spent on each of the tests. This result showed that the problem-solving skill of the concept mapping achievement test and the transfer test may have been due to differences between the two groups in the amount of time. They are several possibilities performance for the beneficial effects of the concept mapping.

7. Conclusion and implications

The finding clearly perform that concept mapping can benefit students automotive problem solving skill. Student may promote their instruction by adopting concept mapping as a learning strategy. Because concept mapping is a self-directed learning strategy that does not rely on traditional learning environment, it is beneficially adopted by users. Moreover, concept mapping is challenging task, for which they have more corresponding personal or vicarious experience to refer, it is important to perform faulty diagnosis. In regard to automotive students, it remains to be seen whether concept mapping would lead to equally large gains in achievement. Students can differ in their knowledge representation with motivations and outcomes when learning a challenging task.

Acknowledgement

The researcher would like to thank especially like to express gratitude for the funding support of the Office of National Research Council of Thailand (NRCT) in Phase II (B.E. 2554). The researcher also would like to thank especially to NISSAN Motors (Thailand) Co., Ltd for the contribution support of Training managers and experts. Janet Zaleski Burns contributed in the discussant comments for developing of the paper. C. Keith Waugh assisted in the information of the presentation program.

References

Bloom B. S. (1956). *Taxonomy of educational objectives, Handbook I: The cognitive domain.* New York: David McKay Co Inc.

Cline, B. E., Brewster, C. C., & Fell, R. D. (2010). A rule-based system for automatically evaluating student concept maps. *Expert Systems with Applications, 37*, 2282-2291.

Duffy, J.E. (2000). *Modern automotive technology (5th ed).* Illinois: The Goodheart-Willcox.

Feltovich, P. J., Spiro, R. J., Coulson, R. L., & Feltovich, J. (1996). Collaboration within and among minds: Mastering complexity, individually and in groups. In T. Koschmann (Ed), CSCL: Theory and practice of an emerging paradigm (pp. 25-44). Mahwah, NJ: Lawrence Erlbaum Associates.

Haugwitz, M., Nesbit, J. C., & Sandmann, A. (2010). Cognitive ability and the instructional efficacy of collaborative concept mapping. *Learning and Individual Differences, 20*, 536-543.

Jonassen, D.H. (1997). Instructional design models for well-structured and ill-structured problem solving learning outcomes. *Educational Technology Research and Development*, *45*(1), 656.

Jonassen, D.H. (2000). Toward a design theory of problem solving. *Educational Technology Research & Development, 48*(4), 63−65.

Jonassen, D. H. (2004). *Learning to solve problems: an instructional design guide.* San Fransisco, CA: Pfeiffer.

Jonassen, D. H., & Hernandez-Serrano, J. (2002). Case-based reasoning and instructional design: Using stories to support problem solving. *Educational Technology Research and Development, 50(2),* 65-77.

Jonassen, D. H., & Hung, W., (2006). Learning to troubleshooting: A new theory-based design architecture. *Educational Psychology Review, 18*(1), 77-114.

Hilbert, T. S., & Renkl, A. (2009). Learning how to use a computer-based concept-mapping tool: Self-explaning examples helps. *Computers in Human Behavior, 25*, 267-274.

Kolodner, J. (1993). *Case-based reasoning*. San Mateo, CA: Morgan Kaufman Publishers Inc.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*, 159-174.

Mintzes, J. J., Wandersee, J. H. & Novak, J. D. (1997). Teaching science for understanding. San Diego, CA: Academic Press.

National Automotive Technicians Education Foundation (NATEF). (2008). ASE program certificatation standards for automotive technician training programs. Retrieved September 19, 2008, from Web site: http:// www. natef.org

Novak, J. D. (1990). Concept mapping: a useful tool for science education. *Journal of Research in Science Teaching, 27*(10), 937−49.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

O'Donnell, A. M., Dansereau, D. F., & Hall, R. H. (2002). Knowledge maps as scaffolds for cognitive processing. *Educational Psychology Review, 14*, 71-86.

Perez, R. S. (1991). A view from troubleshooting. In Smith, M. U. (ed.), Toward a Unified Theory of Problem Solving, Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Phye, G. D. (2001). Problem-solving instruction and problem-solving transfer: The correspondence issue. *Journal of Educational Psychology, 93*(3), 571-578.

Plotnick, E. (1997). Concept mapping: a graphical system for understanding the relationship between concepts. Eric Digest, ED407938. Retrieved March 2009 from ERIC Database.

Pohl, M. (2000). *Learning to think, thinking to learn: Models and strategies to develop a classroom culture of thinking.* Cheltenham, Vic.: Hawker Brownlow.

Renkl, A., & Atkinson, R. K. (2007). An example order for cognitive skill acquisition. In F. E. Ritter, J. Nerb, E. Lehtinen, & T. M, O'Shea (Eds.), In order to learn: How the sequence of topics influences learning (pp. 95-105). New York, NY: Oxford University Press.

Schaafstal, A., & Schraagen, J. M. (1993). The acquisition of troubleshooting skill implication for tools for learning. In Brouwer-Janse, M. D., and Harrington, T. L. (eds.), *Human-Machine Communication for Educational Systems Design*, Springer-Verlag, New York, pp. 107-118.

Shin, N., Jonassen, D. H., & McGee, S. (2003). Predictors of well-structured and ill-structured problem solving in an astronomy simulation. *Research in Science Teaching, 40(1),* 6-33.

Sudsomboon, W., & Anmanatarkul, A. (2009). A study of contextual conditions on problem solving skills training program for automotive service technicians. *Proceedings of the 2nd International Conference on Educational Reform (ICER 2009)*, Thailand, 131−148.

Sudsomboon, W. (2010). Learning innovation in technology: Towards a training package for sustainability training to solve the problems. *Journal of King Mongkut's University of Technology North Bangkok, 20*(1), 17-27.

Thalheimer, W., & Cook, S. (2002, August). How to calculate effect sizes from published research articles: A simplified methodology. Retrieved February 15, 2011, from http://work-learning.com/effect_sizes.htm.

Uribe, D., Klein, J.D., & Sullivan, H. (2003). The effect of computer-mediated collaborative learning on solving ill-defined problems. *Educational Research Technology and Development, 51*(1), 5-19.

Voss, J. F., & Post, T. A. (1988). On the solving of ill-structured problems. In M. H. Chi, R. Glaser, & M. J. Farr (Eds.), The nature of expertise (pp. 261-285). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Yin, Y., Vanides, J., Ruiz-Primo, M. A., Ayala, C. C., & Shavelson, R. J. (2005). Comparison of two concept-mapping techniques: implications for scoring, interpretation, and use. *Journal of Research in Science Teaching*, *42(2)*, 166−184.

Table 1: *Means and standard deviations of dependent variables across groups*

Dependent measures	Treatment					
	Concept mapping approach			Case-based learning		
	Low[a] (*n* = 12) *M (SD)*	High (*n* = 11) *M (SD)*	Total (*n* = 23) *M (SD)*	Low[a] (*n* = 13) *M (SD)*	High (*n* = 12) *M (SD)*	Total (*n* = 25) *M (SD)*
Problem-solving skills						
Concept mapping Achievement[b]	50.6 (5.03)	54.1 (6.67)	52.3 (5.85)	48.6 (5.91)	47.4 (6.37)	48.0 (6.14)
Case-base learning Achievement[c]	47.2 (3.19)	50.5 (4.08)	48.8 (3.64)	41.3 (2.17)	44.6 (3.86)	42.95 (3.02)
Transfer						
Transfer test[d]	48.4 (6.37)	51.8 (4.82)	50.1 (5.59)	44.1 (7.29)	46.9 (6.57)	45.5 (6.93)
Time on test (min)						
Concept mapping achievement	19.3 (5.69)	18.2 (6.48)	18.7 (6.08)	17.4 (3.68)	16.8 (2.96)	17.1 (3.32)
Case-base learning achievement	16.3 (3.21)	15.7 (2.85)	16.0 (3.03)	14.2 (4.39)	13.5 (3.11)	13.8 (3.75)
Transfer test	18.2 (5.44)	16.9 (4.76)	17.5 (5.10)	14.5 (3.42)	12.2 (2.54)	13.4 (2.98)
Attitudes[e]						
Attention	4.5 (0.88)	4.7 (0.91)	4.6 (0.89)	4.5 (0.74)	4.2 (0.83)	4.3 (0.78)
Motivation	4.8 (0.76)	4.8 (0.88)	4.8 (0.82)	4.5 (0.86)	4.4 (0.92)	4.5 (0.89)
Satisfaction	4.9 (0.54)	4.8 (0.32)	4.9 (0.43)	4.8 (0.65)	4.5 (0.88)	4.6 (0.76)
Application	4.6 (0.63)	5.0 (0.55)	4.8 (0.59)	4.5 (0.89)	4.4 (0.92)	4.4 (0.90)