INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

Interdisciplinary Programme in Education Technology

S Y N O P S I S

of the Ph. D. thesis entitled

THE USE OF CONCEPT MAPS AND AN INSTRUNCTIONAL DESIGN MODEL IN THE CLASSROOM TEACHING OF THERMODYNAMICS AND INTERNAL COMBUSTION ENGINES

Proposed to be submitted in

Partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

of the

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

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Synopsis

The present thesis entitled **“The use of concept maps and an instructional design model in the classroom teaching of thermodynamics and Internal combustion engines”** is organized into thirteen Chapters. Currently, present engineering education system makes use of diverse kinds of instructional methods and innovative teaching methods for teaching engineering concepts (Cuban, 1986). Such implementation of innovative teaching methods and affordable technologies are employed with the expectation of reforms in engineering education. Even after spending at least four years in the undergraduate programmes, a majority of students do not develop a good understanding of the basic principles involved in the theory of engineering as well as applying the learning in real life situations. In mechanical engineering curriculum, thermodynamics and internal combustion engines are core subjects and student are facing difficulties in understanding concepts in these subjects (Mulop et al., 2011, Bahr, 1999, Huang and Gramoll, 2004, Anderson et al., 2002, 2005). The present work will elaborate on the current problems in engineering education and the specific difficulties in teaching thermodynamics and internal combustion engines. A solution to the problem will only emerge if the learning processes are strengthened by addressing all major components that go into the process of learning. Chapter 1 discusses the process of meaningful leaning, taxonomy of learning, learning styles and explore various strategies for improving learning styles. The implementation of concept maps as a teaching- learning method constitutes a major component of the present study. After this, instructional design (ID) models will be outlined. Although there are a large number of ID models, we have found it to be very convenient to adopt the ASSURE ID model in our work.

Chapter 2 discusses concept maps and its applications in engineering education. Concept maps are visual representations of knowledge. This knowledge representation is of concepts and the relationship between concepts. The tool of concept maps is used to foster meaningful learning as well as an evaluation tool. (Novak and Gowin, 1984; Novak, 1998; Mintzes, et al., 2000). Concept Maps are also effective in identifying both valid and invalid concepts held by students (Edwards and Fraser, 1983). In the creation of concept maps, learners are engaged in a creative process and this can be challenging for many students as they are following rote learning for many years. The seven point method of generating concept maps devised by Novak and Gowin (1984) has been implemented in the present work.

Chapter 3 summarizes a description of the methods and procedures used in the present study. The topics were chosen as ***the first law of thermodynamics*** and ***the second law of***

thermodynamics for second year mechanical undergraduate, ***introduction to the internal combustion engines (IICE)*** for third year mechanical undergraduates as these topics are perceived as difficult topics by many experts as discussed in the Chapter 2. The objectives of the present study are as follows:

I. The first objective of the current study was to investigate the effects of use of concept mapping strategy in the classroom teaching of laws of thermodynamics and internal combustion engines.

II. The second objective of the present study is to investigate the combined effect of concept mapping and an online course module in the classroom teaching of internal combustion engines.

III. The third objective of the study was to investigate the effects of use of ASSURE Instructional design (ID) model in the teaching of the laws of thermodynamics.

In this study, the independent variable is using or not using concept maps/ combined use of online course module along with concept maps / ASSURE ID model while learning and the dependent variable is the students' achievements in the respective topics. We used two objective tests to measure achievement of the students. One of the tests measured students' pre-requisite knowledge in topics of thermal engineering or science. At the end of teaching of the topic, the post test was conducted.

Participants in this study were mechanical engineering undergraduate students from the University of Mumbai, India. They were randomly divided into two groups. One group was randomly assigned as the experimental group; the other group was used as the control group. The experimental group utilized the treatment (either concept maps or combined use of concept maps and online course module or ASSURE ID model) while learning. The control group was taught the same topic with the traditional teaching method. The teacher and the textbooks for both groups were the same in order to avoid confounding effects on the experiment. Content validity of the questions was achieved by consulting with another expert teacher from the same college. No student in the class reported previous experience in active learning methods for the given topics.

We used two objective tests to measure achievement of the students. One of the tests measured students' pre-requisite knowledge in topics of thermal engineering. The second test (post test) measured students' achievement in topic of study. A satisfaction questionnaire was given to the students at the end of the study to examine the attitude of students towards the use of teaching- learning strategy to learn the given topics. The questionnaire comprised of 10 items, and was rated on a five-point Likert scale from 'strongly disagree' to 'strongly agree'. Bloom's taxonomy (1969) was used to ensure that test items in the post test were at the different cognitive levels. The test questions used in this study are at the knowledge, comprehension, and application and above level questions.

Some important concepts from statistics are included in Chapter 4 to provide ready support in analyzing the results presented in the later chapters of this report. It is also written with the perceptive of studies in thermodynamics and mechanical engineering.

Chapter 5 discusses implementation of the concept maps as a teaching-learning strategy in the second year mechanical engineering students (Year 2013) to evaluate students' understanding of the first law of thermodynamics. In the classroom teaching of the first law of thermodynamics, the achievement of the experimental group was found to be not significantly higher than that of the control group which was taught with the traditional teaching method. The results however support the use of concept mapping at low level cognitive questions (knowledge level) in the classroom teaching of the first law of thermodynamics. Concept maps were successful tools in helping low achievers improve their grades at knowledge level questions. This suggests that concept maps help students with both low and high abilities at the knowledge level in the topic of the first law of thermodynamics.

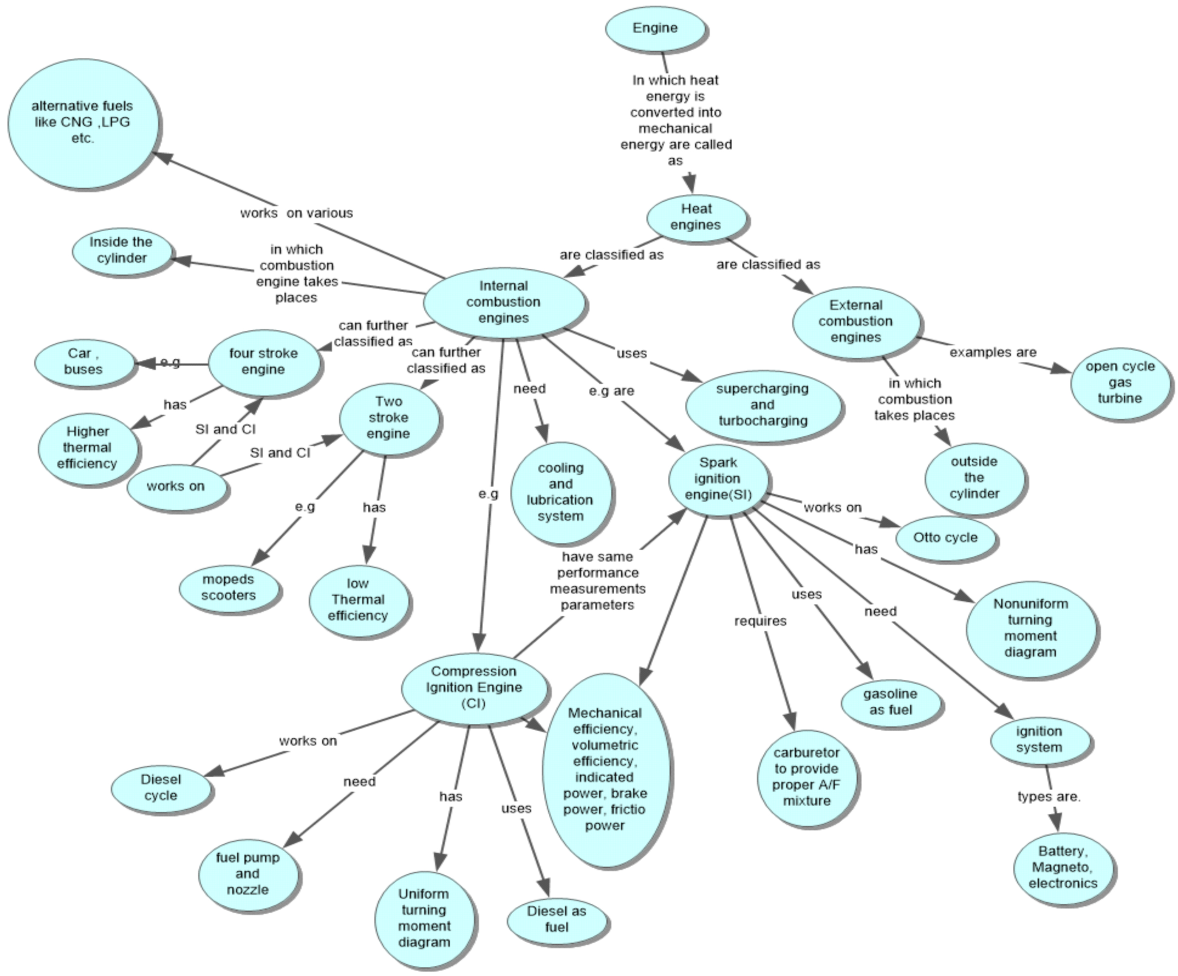
Chapter 6 describes the effect of concept maps on learners' achievement and interest for classroom teaching of the second law of thermodynamics to the second year mechanical engineering students (Year 2012- Method 1). The results of the present study support the use of concept maps for engaging students in constructing their own knowledge structures in the topic of the second law of thermodynamics and its impact at various levels of understanding. The study also supports the use of concepts maps in improving the overall performance of the students. Use of concept maps improves the performance of the students at high cognitive levels of learning (comprehension, application and above).

Constructing concept maps helps low ability students more than high ability students at the comprehension level and it helps the high ability students' more than low ability students at the application level. Thus, concept mapping is a successful tool for both low ability and high ability students. Concept mapping can be used to identify weaker areas of learning such as the principle of increase of entropy, the relationship between Carnot theorem and the thermodynamic temperature scale and equivalence of the Kelvin- Planck statement and the Claussius statement. In conclusion, concept maps represent a good way to assess, and gain insights into how students learn the relationships among concepts.

Chapter 7, we have implemented concept maps as an active learning method in the topic of Introduction to Internal Combustion Engines (IICE) for third year mechanical engineering students in the year 2012. This study has been divided in two parts: firstly we have implemented concept mapping strategy in the topic of IICE in experimental design. Secondly we used concept mapping strategy for problem solving in the topic of IICE. Results showed that the mean score of the post test for the experimental group was higher than that of the control group and the experimental group outperformed control group. The results suggest that the concept mapping strategy improved the students' learning achievement than the traditional teaching methods. This finding is in agreement with earlier findings in other disciplines (Ahlberg, et al. 2005; Arnaudin, et al. 1984, Chularut et al. 2004 ; Cliburn ,1990; Lavigne,,2005; Ritchie ,2000). Our analysis dealt with the differential effect of concept mapping on cognitive levels of questions in the post test. Results show that the experimental group was having higher mean scores in knowledge recall test and knowledge application test. These results suggest that concept mapping helped students in the experimental groups to achieve better cognitive level. Younus (2010) got similar results in the study of ninth grade physics students.

In the second method as described in Chapter 7, the present study investigated the effect of concept mapping strategy on the performance of the students in problem solving. The study was done on a sample of 84 third year undergraduate mechanical engineering students. The subject of the study was internal combustion engines at a college of engineering of the University of Mumbai. The study used a pre-test and post-test quasi-experimental design method on a control group and an experimental group. The result of present study suggests that students exposed to the use of concept mapping strategy more effectively improved the student's performance in problem solving than the traditional teaching method. The result of this study shows that students exposed to the use of concept mapping technique while studying IICE significantly higher in well structured problem solving than those students to traditional teaching method. It is in line with the findings of Braselton and Decker (1994), Nnamdi Okoye and Okechukwu (2006). Using concept mapping strategy, performance of the students in well structured problem solving improved.

Chapter 8 presents a case study on the use of concept mapping as a teaching- learning strategy in the classroom teaching of the topic introduction to the internal combustion engine IICE) in an undergraduate mechanical engineering course in the year 2014.



The results of quantitative analysis showed that the two groups did exhibit significant difference in students' achievement. The results show that students who are using concept maps are actively involved in knowledge creation process. This results in deeper learning. The results of quantitative analysis using Bloom's taxonomy indicate that students using concept mapping performed better than those not using concept maps in terms of the cognitive levels of understanding of concepts and creating of concepts. Further analysis takes into account the interaction between gender and groups. There are no significant interactions in the total scores, knowledge level scores, the comprehension level scores, application level scores and numeric level scores between different genders. Both men and women are having the same learning ability at total achievement, knowledge level, comprehension level, application level and numerical level.

We also considered the differential effect of using concept maps on high and low achieving students. Significant differences were observed at the knowledge levels and numerical level. No significant differences were found in the total achievement level and comprehension levels.

In chapter 9, we have utilized the online course material for the topic of IICE which was created by us. The online course was made by us on *Elidemy* which is a free e-learning platform to create, share and manage online courses. Our results indicate improvement in total performance of the students as well as performances at lower levels of learning namely, knowledge and comprehension. The present study shows that the preferred learning styles of the students are reflective observation, abstract conceptualization and doing active experimentation. Taking into consideration the students' learning styles, we have implemented and examined the effectiveness of active learning methods. We are also able to see the learning processes through the concept maps drawn by the students. The results in the present study should encourage engineering teachers to design more active learning methods which would help student's engagements in deeper learning.

Chapter 10 discusses Instructional design (ID) model and its implementation in classroom study. ID is a system of procedures for enhancing education in a consistent manner (Gustafson and Branch, 2002). Several systematic instructional design processes have been suggested. The ASSURE model is an ISD (Instructional Systems Design) process that was modified to be used by teachers in their classroom. It was developed by Heinich, Molenda, Russell and Smaldino, in Instructional Media and Technologies for Learning. Our study uses the ASSURE ID model to investigate its effect on the students' understanding of first and second law of thermodynamics in a section of the second year mechanical engineering students in the year 2013.

In the use of ASSURE ID model in the classroom teaching of the first and second laws of thermodynamics, the achievement of the experimental group was found to be significantly higher than that of the control group which was taught with the traditional teaching method. ASSURE ID model was successful tools in helping both low achievers and high achievers to improve their grades at total thermodynamics achievement score and knowledge level questions in both the laws of thermodynamics. The students reacted positively to the use of ASSURE ID model.

In the Chapter 11, we have tried to find whether there is correlation between marks of the students in the topic of IICE and their previous year's marks in various subjects. The marks of the students in the post test in the topic of IICE at the different cognitive level were correlated with the their class X marks, class XII marks, their marks in physics in XII standard, their marks in mathematics in XII, marks in thermodynamics and marks in the subject computer programming. It is found that marks in the total test are moderately related with their marks are related with their marks in mathematics ($r = 0.451$) and their marks in computer programming ($r = 0.292$).

Collaborative concept mapping (CCM) can provide more stimuli to enhance learning than individual concept mapping (Gao, et al., 2007). In the chapter 12, we investigate how different approaches of making concept mapping influence the learning. Specifically, how third year mechanical engineering students learn the topic of introduction to the internal combustion engine (IICE) when they construct concept maps alone and when students learn the topic of IICE when they construct concepts maps in groups. The findings provide evidence that computer based collaborative generating concept maps during study time positively influences IICE learning and can be facilitative. Research findings do support the assumption that collaborative learning is more effective than learning individually. Students enjoyed '*Inspiration*' software which supported their construction of concept maps for IICE and helped them capture their quickly solving ideas and organize them for meaningful learning. These findings provide evidence that constructivist learning theory is correct regarding learners' needs to organize and represent concepts visually and explore interrelationships among concepts. The findings do support assumption that collaborative knowledge construction is more effective than individual knowledge construction (Liu, 2004; Novak, 1998; Roth and Roychoudhury, 1993; Wellington and Osborne, 2001; Yin et al., 2005).

Finally, lessons learned and suggestions for future work are highlighted in Chapter 13.

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List of Published Papers:

1. **S. K. Kamble**, B. L. Tembe. Teaching of the second law of thermodynamics: Evaluation of learners' concept maps, ***International Journal of the Computer, the Internet and Management***, *IJCIM*, Vol.20, No.2, May- August 2012, ISSN 0858-7027, pp. 17-21.

2. B. L. Tembe, **S. K. Kamble.** ***Journal of Learning in Higher Education (JLHE)***, spring 2013, ISSN: 1936-346, Vol. 9, Issue 1, pp.129-135.

3. **S. K. Kamble**, B. L. Tembe. The effect of use of concept maps on problem solving performance and attitude in Mechanical engineering course, ***Procedia – Social Science and Behavior***, July-2013, Vol. 83, pp-748-754.
4. **S. K. Kamble**, B. L. Tembe. The effect of concept maps on achievement and attitude in a Mechanical engineering course, ***IEEE International Conference on Teaching, Assessment and Learning for Engineering,*** **(TALE-2012),** 20th -23rd August 2012, Hong Kong.
5. B. L. Tembe, **S. K. Kamble.** Concept mapping as an assessment tool for teaching thermodynamics to mechanical engineering students, ***Sixth International Conference on Concept Mapping,*** (CMC 2014), 23rd September-25th September, 2014, Brazil.
6. **S. K. Kamble,** B. L. Tembe. The use of concept Maps in the teaching of the second law of thermodynamics to engineering students. ***1st International Conference and 5th CSI National Conference on Education and Research (confER-2012),*** (Applications of Foss in Education and Research), 12th-13th January, 2012, Lingaya's University, Faridabad, India.
7. **S. K. Kamble**, B. L. Tembe. Computer assisted collaborative concept mapping in engineering education. Submitted. ***5th International Conference on Educational and Information Technology (ICEIT 2016)*** will be held during **March 17-18, 2016** in **Paris, France**, organized by American Society for Research (ASR).

8. **S. K. Kamble,** B. L. Tembe. Implementation of active learning methods in mechanical engineering education to enhance students' performance. Submitted to the ***40th IEEE Computer Society International Conference on Computers, Software and Applications,*** Atlanta, Georgia, USA - June 10-14, 2016.
9. S. K. Kamble, B. L. Tembe**.** Concept maps as a form of students assessment and instruction in mechanical engineering education**.** To be submitted in ***International***

Journal of Mechanical Engineering Education.

10. S. K. Kamble, B. L. Tembe. **The impact of concept mapping on achievement and attitude in a thermodynamics course.** To be submitted in *International Journal of Engineering Pedagogy.*