Teaching of the Second Law of Thermodynamics: Evaluation of learners’ concept maps

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Abstract

The present study describes the effect of concept maps on learners’ achievement and interest for classroom teaching of the second law of thermodynamics to engineering students. Learners are encouraged to develop their individual concept maps of the second law of thermodynamics.

The scores of the learners’ concept maps are compared with the score of the expert map developed by the teacher. After teaching the topic, an achievement test about the second law of thermodynamics consisting of 15 questions was administered. Concept map scores and the results of achievement test were compared. Experimental data reveals that concept map scores are moderately co-related with the scores of achievement test. While achievement test measures application knowledge, the concept maps on the other hand measure knowledge about related concepts and degree and quality of relationships constructed between the concepts.

As a result, concept maps can be used as an assessment method along with achievement test to measure various aspects of learning. Learners’ perceptions indicate the effectiveness of the use of concept maps in the classroom. An analysis conducted on learning outcomes is also presented.

Keywords: Concept maps, The second law of thermodynamics, achievement test, meaningful learning, Cronbach alpha coefficient, K-R 20 coefficient

I. INTRODUCTION AND OVERVIEW OF CONCEPT MAPS

Teaching thermodynamics is often considered as a challenge because the concepts are abstract, difficult to apply in different situations and difficult to visualise. It is considered a difficult course for mastery of concepts, principles, and procedures [1-5]. Many of the learners do not develop significant abilities in thermodynamics because they are not constructing appropriate understanding of its fundamental concepts. The second law of thermodynamics is the one where the impacts are even more profound than the first law of thermodynamics as far as the behaviour of matter in natural (irreversible) processes is concerned. The second law of thermodynamics can be interpreted in different ways. This second law of the dynamics is one of the most interesting laws of nature. It has generated considerable controversy and confusion.

According to Ausubel, in meaningful learning, new knowledge interacts with the existing relevant concepts and is assimilated into these concepts [6]. Concept maps are simple tools that can be useful for detecting possible shortages of understanding and learning of basic concepts. Concepts maps were developed by Novak in 1972 as a
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representative part of meaningful learning [7]. Concept mapping is a meta-learning strategy that can be used to develop learner’s capacity to learn independently. Concept maps are a procedure that is used to measure the structure and organisation of an individual knowledge. One of the advantages of using concept mapping is that it makes learning easier; it provides visual representation of knowledge. It makes reviewing of knowledge easier. Concept maps can be used as a knowledge representation tool to reflect relationships between concepts that are stored within learner’s long term memory. When producing a concept map, the attention is focussed on the relationship among various concepts. Concept maps reveal the concepts already present in learner’s mind, the conceptual connection between the concepts and the growth that takes place as a result of teaching and learning process [7]. These maps consist of concepts and correct statements about a subject enclosed in oval ‘boxes’. These are the basic elements of a concept map. These basic elements of a concept map are connected together by linking words (prepositions) in a hierarchical structure. As we move down in the map, the specificity level of the concepts increases. Cross links are used to show the connection between the various concepts. Researchers have found that concept maps are useful to assess prior knowledge, to identify gaps in students’ knowledge, to help a teacher to identify key concepts to target in their teaching and as an assessment tool to determine the extent and quality of new connections that the learners are able to make after the instructions [8]. Concepts maps have been adopted in the studies from physical sciences to ecology and business setting [8].

II. OBJECTIVES OF THE STUDY

To our knowledge, there is little published work on concept mapping in the subject of thermodynamics. This study was conducted for addressing the following objectives:
1. To develop and implement concept mapping as a teaching learning strategy for the topic of the second law of thermodynamics.
2. To assess learners’ understanding of concepts of the second law of thermodynamics by comparing and contrasting two different methods, namely, concept maps and achievement test.
3. To investigate whether a correlation exists between achievement of learners’ in the topic of the second law of thermodynamics and their performance in creating concept maps.
4. To study the attitude of the learners’ towards concept mapping for the second law of thermodynamics.

III. METHODOLOGY

There are several ways in which a student can create concepts maps. Many softwares are also available for this purpose. The methodology used in this paper is of the type where the learners produce their own concept maps and their maps are compared with the expert map created by subject experts. An example of an expert’s concept map has been given in our earlier paper [9]. Participants in this study were 46 second year mechanical engineering students from the University of Mumbai, India. Study was conducted over a six lecture module on the second law of thermodynamics. At the start of the first hour, training was given for 50 minutes about creation of concept maps.

This study has used following approach for producing learners’ concept map [10-12]. The learners were introduced to concept maps and their characteristics features. A list of concepts that are included in the second law of thermodynamics is prepared in the class. The rubrics to score the concept maps are explained to the learners. The learners are asked to create their own concept maps.
of the second law of thermodynamics. An achievement test was conducted for the topic of the second law of thermodynamics that measures of application of learners’ knowledge. This test of 15 questions was developed by the teacher and has a K-R 20 coefficient (reliability factor) of 0.63.

The assessment of the concept maps has been carried out in quantitative and qualitative way [7, 8]. For the quantitative assessment of the concept maps, a structural scoring method is used [7, 8]. In the structural scoring method, concept maps are scored for identifying correct prepositions, the presence of different levels of hierarchy, the presence of cross links and the particular examples given by learners. The final score is the sum of all those scores [8]. In the scoring scheme, five marks are given for prepositions, ten marks for hierarchy, and ten marks for cross links and five marks for particular examples given by the learner.

The participants’ scores were rated out of 30 for the creation of the concept map and then compared with the achievement test. Here the Pearson correlation factor (r) was found to be 0.334. This level of correlation was meaningful but moderate.

The learners’ perception about concept map was measured with a questionnaire using a five point Likert scale. The learners were required to give a rating of their agreement to a given statement on a scale of 1(strongly disagree) to 5 (strongly agree).

IV. RESULTS AND DISCUSSION

In order to establish the relation between the scores in achievement test and concept map, these two scores are plotted against each other and shown in Figure 1.

![Fig. 1 Relationship between achievement test score and concept map score](image)

Figure 1 show that there is a moderate relationship between the learners’ achievement in the topic of the second law of thermodynamics and their performance in the creation of the concept map and Pearson correlation factor (r) was found to be 0.334.

In order to understand the reasons for this moderate correlation, we selected the learning objectives directly related to the second law of thermodynamics and compared the two scores for these learning objectives. It was found that in the learning objectives consisting of a) writing various statements of the Second law of thermodynamic and b) writing statements illustrating concepts of entropy, there is a very strong similarity (within about 20%) between concept map scores and achievement test scores. In the learning objectives of a) writing statements about PMM (perpetual motion machine) 2, b) writing statements about the principle of increase of entropy, c) writing the conditions about executing the cyclic process and d) writing statements about the thermodynamic temperature scale, the differences in the two scores are well over 50%. These findings indicate that we need to develop robust
strategies for the teaching of the second set of learning objectives given above.

It can be seen that learners were able to write about the principle of entropy in the achievement test but were unable to connect equally well in the concept map. Similarly, they were unable to connect well concepts like thermodynamic temperature scale and PMM2, in the concept map.

Learners’ performance on concept maps has been found to be moderately correlated with the more conventional tests such as multiple choice tests. The strength of the correlations have been found to vary depending upon three factors: the type of test, type of concept map generation and rubric for scoring concept map [13].

In order to examine and evaluate the learners’ attitude towards concept mapping and the use of this tool in thermodynamics classroom teaching, questionnaires were administered to the students [10]. The students were questioned on several aspects of the concept mapping tool and its use in the classroom including personal information, the concept mapping tool itself and finally the impact it had on their learning. The reliability estimate based on the Cronbach alpha (measure of internal consistency) is 0.82, which is consistent with reliability estimates of perceptions questionnaires from other such studies who obtained reliability estimates from 0.5 to 0.9 [12, 13]. The majority of the learners were in favour of the use of the concept maps in the classroom. In total 46 responses were collected from the learners. About 63% learners are in favour of concept map as tool to see a big picture of the topic of the second law of thermodynamics. About 91% learners are saying that the concept maps helps in understanding the relationship between the various concepts. About 67% learners are saying that it helps in problem solving capacity of the students. About 91% learners are saying that it helps in understanding the logical flow concepts. The majority of the learners found concept maps to be helpful in seeing a ‘big picture’. Students generally perceive that the learning objectives were met except for a few topics like the principle of increase of entropy and problem solving competence in entropy calculations in various processes. The reliability estimate for the questionnaires for achieving learning objectives of the second law of thermodynamics based on the Cronbach alpha method is 0.90. These topics need to be discussed in detail and explained with examples.

V. CONCLUSIONS

In the present study, we found that there is a moderate correlation between the learners’ performance in the conventional test which measure application of knowledge and their performance in the creation of the concept map. It is found that the learners are comfortable with the creation of the concept maps. The learners reacted positively to the tool of concept map and feel that it has several benefits to their learning of the second law of thermodynamics.

Research findings indicate that even though the learners performed better in achievement test than in the creation of concept maps; they had difficulties in establishing the relationship between these concepts. Most of the learners were able to apply the various concepts in different situations but were unable to establish the relationship among these concepts.

Thus, concept map is an assessment method that plays a supplementary role to the conventional achievement test and it measures other aspects of learning that achievement test can’t measure such as relationship among different concepts, incorrect conceptions.
REFERENCES


