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Computer based Concept maps as a tool for assessment for meaningful learning

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***Abstract*— The present study investigates use of blended concept map technique appliedtothethermodynamics inthesecond year ofMechanicalengineeringofUniversityofMumbai, India. Two studies have been designed. In one study, traditional teacher leaning was followed to learn the topic of thermodynamicsandinanotherstudy,studentstaughtthesametopic withconcept mapusingsoftware. The present work shows that there is significant difference between test score of pre and posttests who uses concept maps. Students showed positive inclination towards use of concept maps.**

Keywords—**Concept maps, meaningful learning, Bloom's taxonomy.**

***JEET Category*— Research**

I. INTRODUCTION

Engineering education have implemented various innovative strategies at university level at national level as well as international level. This change was needed to make students ready for lifelong meaningful learning [1].

There are three types of learning strategies for meaningful learning. In the first strategy of metacognitive, students are assessed on their present knowledge, evaluating of the need for new knowledge, and strategies to enhance the new knowledge[2.3,4]

The third strategy is social strategy, which are also called affective strategy. In this strategy, group discussion takes place in which exchange of ideas takes place. The concept maps is one of the metacognitive strategies, which improves meaningful learning [4].

II. CONCEPT MAPS

In 1972, Novak developed concept maps for meaningful learning. These concept maps were based on the theory of Ausubel of constructivism. In the theory of constructivism, role of teachers to help learners to become active learners by building their knowledge with the help of their previous experience. Concept maps shows various ideas in a hierarchical manner. Concept maps connects ideas with explanation and links. Two or more concepts ideas can be connected to generate a preposition. (Figure 1).

Previous research shows that concept maps have positive effect on the quality of students learning. Concepts maps have been successfully used invidious domains such as higher education. As per De Simone, engagement in concept mapping demands that learners take an active stance in their learning process. In the concept maps, learners created new ideas and knowledge. The concept maps technique replaces traditional teaching of rote memorization and passive learning.

III. AIMS

The primary aim of this study is to assess the utilization of concept maps as a learning technique within the context of thermodynamics for second-year mechanical engineering students. The purpose of the study is to improve teaching-learning process of the students. This also aims to teach them correctly how to generate concept maps and to make them aware of learning dynamics.

In this research, we delve into the subsequent three primary research inquiries.

(1) Does the computer based blended learning approach of using concept maps enhances students' learning?

(2) Does the computer based blended learning approach of using concept maps promotes students' performance in the study?

(3) Does the computer based blended learning approach of using concept maps improve students' perception towards concept mapping?

IV. METHODOLOGY

In this study, 72 second year mechanical engineering students took part from the University of Mumbai, India. These 72 students were randomly divided into two groups. The topic selected was the second law of thermodynamics. One group was having 35 students (n = 35, 27 males, and 8 females, see Table 1), and this group was experimental group. Another group was assigned as control group and was having total 37 students (n = 35, 27 boys and 08 girls, Table 1).

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The experimental group was taught with computer-based concept maps along with traditional teaching. The control group received instruction on the identical subject matter using conventional teaching methods. The same teachers was there for both the group.

TABLE 1 DETAILS ABOUT EXPERIMENTAL AND CONTROL GROUPS

	Experimental group		**Control group**		**Total**
Gender	n	%	n	%	n
Male	27	77.12	30	81.08	57
Female	08	22.85	07	18.91	15
Total	35	100.0	37	100.0	72

Legend: n represents number of students in a given group, % represents percentage/proportion of students in a given group.

Test score in the second law of thermodynamics

The study examines assessments related to the second law of thermodynamics to measure student achievement. In this research, student achievement serves as the dependent variable. The study employs Bloom's taxonomy (as depicted in Figure 1), which encompasses various cognitive levels for the assessment questions. Bloom's taxonomy encompasses various levels, including knowledge, comprehension, application, analysis, evaluation, and synthesis, with knowledge serving as the foundational level. This taxonomy advances from fundamental, lower-level cognitive skills to more complex, higher-level cognitive abilities. The questions employed in the test are at various levels, namely application, knowledge, and comprehension levels. The application and above level contain questions which include analysis, evaluation and synthesis levels. The post-test carries 44 questions based on the topic of thermodynamics.

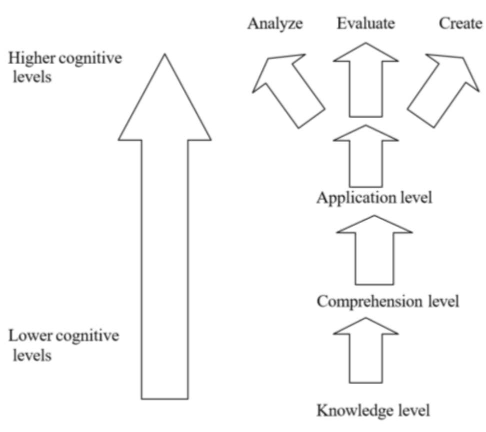

Figure 1. Bloom's Taxonomy (Taken from Anderson and Krathwohl, 2001)

Based on the Bloom's taxonomy, the distribution of questions concerning the second law of thermodynamics in the post test is as presented in Table 2.

TABLE 2 VARIOUS LEVELS OF QUESTIONS BASED ON THE BLOOM'S TAXONOMY

Level	**The second law of thermodynamics**
Knowledge (KL)	15
Comprehension (CL)	18
Application andAbove (AL)	11
Total questions (TL)	44

V. CONCEPT MAP SCORING RUBRIC

Novak and Gowin (1984) concluded out that concept maps should be hierarchically structured. However, other researchers have shown that these hierarchical structures are not always necessary (Kinchin, 2014). The present report focused on the maps' Novak's hierarchical structure rather than graphic structure due to its ease of assessment and better knowledge representation.

In the present study, Concept map scoring method which was developed by Novak and Gown. Following table shows scoring method.

Sr.No.	**Element**	**Score**
01	Valid Preposition	01
02	Level of hierarchy	05
03	Valid cross link	10
04	Specific example	01

Though above method is time consuming but it reveals information about student's knowledge structure.

Figure 1(attached in the end) shows the expert map of the second law of thermodynamics generated by the teacher. The maps created by the students were compared with the expert map. The scoring of the expert map of the second law of thermodynamics generated by teacher is as follows; 30 marks for valid prepositions, 25 marks for hierarchies, 40 marks for crosslink and 5 marks for examples. The total score of the teacher generated concept map of the second law of thermodynamics is 100.

VI. PROCEDURE

Figure 2 shows a quasi-experimental design. Our study consist of 18 hours teaching and over a period of eight weeks. In a week, the class was delivered three times.

The contents of the classes included the second law of thermodynamics which involved limitations of the first law of thermodynamics, Kelvin Planck statement, Claussius statement, Claussius inequality, the principle of increase of entropy, calculations of entropy changes in various process.

In the first week of the study, the experimental group was taught topics such as utility, attributes and development of concept maps with C-Map software tool. At the end of six-weeks-period, we provided the experimental group a list of concepts developed during the class discussion. They were requested to turn in the concept map. The control group was taught with the traditional teaching method. The concept map scoring was done by Novak method.

After the treatment, students in both the experimental and control groups appeared for the test called as post-test about the second law of thermodynamics.

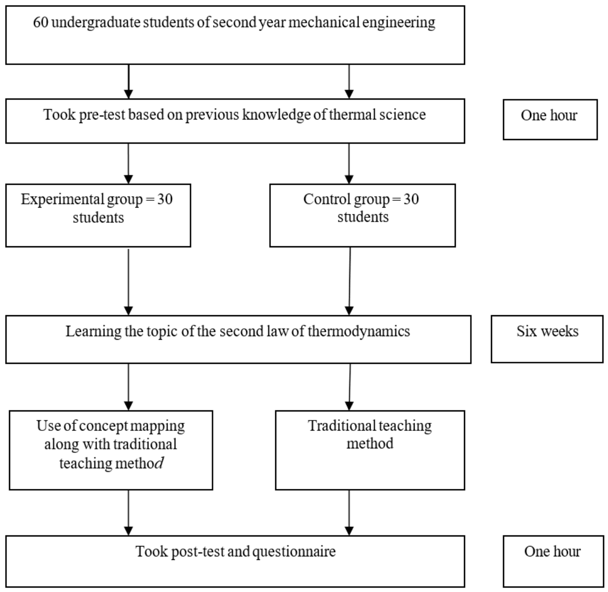

Figure 2. The experimental design

VII. Results

Pre test

The experimental group exhibited an average pretest score of 11.26, while the control group scored an average of 10.00 out of a possible 30 points. Utilizing an independent samples t-test, it was determined that there were no noteworthy distinctions between the two groups ($t = 1.28$, $p > 0.05$).

Post test results of the second law of thermodynamics

Table 3 presents the average and standard deviation values of the results of the post tests for both the the experimental and control groups. The results show scores on levels such as knowledge (KL), comprehension (CL), application (AL) and the total (TL) test. The maximum possible scores are as follows: knowledge level questions = 15, comprehension level questions =18 and application level-and-above questions =11. The maximum total score is thus44. A t-test was undertaken to check if there were significant differences between experimental and control groups on the thermodynamics achievement post results (TL-test). We found significant differences in the total score ($t = 2.90$, $p < 0.05$). A t-test was undertaken to examine at different cognitive levels. No significant difference was found for the questions at the knowledge level (KL-test) ($t = -0.40$, $p > 0.05$). There were significant differences were found at the comprehension level ($t = 3.09$, $p < 0.05$) and application-and-above level ($t = 3.63$, $p < 0.05$).

Table 3 Means and standard deviations in the experimental group and control group

	Experimental group			Control group			t	p value
	N	Mean	SD	N	Mean	SD		
KL-test	35	9.90	2.02	37	8.16	2.99	-0.40	0.688
CL-test	35	7.00	2.85	37	6.86	2.47	3.09	0.003
AL-test	35	6.70	1.55	37	5.40	1.19	3.63	0.01
TL-test	35	23.60	4.42	37	20.43	4.00	2.90	0.005

To assess potential interactions between gender and group factors, a two-way ANOVA was conducted. Table 4 indicates that there was no significant interaction observed between gender and group variables.

Table 4 Analysis of variance for gender-group interactions on the second law thermodynamics achievement post-test (TL-test).

Source	Sum of Scores	df	MS	F
gender	0.53	1	0.53	0.03
group	42.96	1	42.96	2.42
gender - group	56.28	1	56.28	3.17

A two-way ANOVA was performed to explore potential gender-group interactions concerning the various questions related to cognitive levels. Table 5 reveals that there was no statistically significant interaction observed between gender and group specifically in the context of knowledge-level questions.

Table 5 Analysis of variance for gender and group interactions at the knowledge level questions (KL-test)

Source	SS	df	MS	F
gender	3.50	1	3.50	0.53
group	6.06	1	6.06	0.933
gender - group	10.40	1	10.40	1.60

Table 6 shows that there was no significant interaction between gender and group at the comprehension level.

Source	SS	df	MS	F
gender	3.43	1	3.43	0.46
group	47.09	1	47.09	6.43
gender - group	0.13	1	0.13	0.01

Finally, there were significant interaction between gender-group at the application and above level scores (Table 7, $F = 5.08$).

Table 7 Analysis of variance for gender and group interactions on the application and above level questions (AL- test).

Source	SS	df	MS	F
gender	6.74	1	6.74	2.10
group	0.85	1	0.85	0.26
gender - group	16.30	1	16.30	5.08

VIII. Correlation findings

The concept map scores of experimental group was correlated with total test scores. There is a moderated correlation between them (Pearson correlation coefficient = 0.59). Concept map scores were also correlated separately on scores obtained in levels such as knowledge, comprehension and application (Table 8). These results indicate very moderate correlations.

TABLE 8 THE CORRELATION BETWEEN SCORES ON THE CONCEPT MAP AND SCORES ON THE ACHIEVEMENT POST-TEST.

	KL	CL	AL	TL
Concept map score	0.58	0.48	0.45	0.59

IX. STUDENT ATTITUDES AND VIEWS REGARDING CONCEPT MAPPING

The attitudes and views of students about concept mapping in the topic of the second law of thermodynamics, questionnaires were assessed through a questionnaire.

The questionnaire's reliability, as determined by the Cronbach alpha method, is 0.85. The majority of students had a favorable attitude toward the use of concept maps. 92 % students were positive for the use of concept map in thermodynamics, 93 % students expressed that concept mapping is beneficial for studying and revising. 88 % students were in favor of concept map to connect various concepts.

X. DISCUSSIONS

Both pretest and posttest assessments were administered, and a noteworthy discrepancy was observed in the outcomes. Students expressed their views on the utility of concept maps.

The experimental group, which utilized concept maps, demonstrated enhancements in students' learning capabilities. However, when it comes to knowledge-level questions, there was no substantial distinction observed between the experimental and control groups.

There is a significant difference between two groups at comprehension and application and above levels.

The knowledge level is the lowest cognitive level in Bloom's taxonomy. Knowledge level questions contain simple questions like define, list and recall. This study suggests there is no impact of concept mapping on student's achievement at knowledge level.

Concept maps helps students significantly at comprehension and application and above levels. The creation of concept maps includes making of list of concepts, sub concepts, creating linkage (preposition) and giving examples. The creation of concept maps helps students to comprehend, apply analyze, evaluate and synthesize. Comprehension requires understanding the meaning or paraphrasing a concept.

Concept maps of the students were compared with the expert map generated by the teacher. Figure 3 shows the expert map generated by the teacher. They were scored quantitatively according to Novak's criteria. The following conclusions were drawn from the data on the concept maps created. Nearly 70 % percent students were able to write correct statements of the second law of thermodynamics. Only 40 % students were able to write that the Kelvin Planck statement and The Claussius statements are equivalent. Only 45 % students were able to write Claussius inequality. Nearly 85 % students were able state that the secondlaw of thermodynamics leads to a property called 'entropy'. Only 35 % students able to identify that Carnot theorem lead to a thermodynamic temperature scale. Only 45 % students are able to connect the concept of the principle of increase of entropy with the second law of thermodynamics. Concept maps helps in monitor, assess, and understand the complex cognitive processes of students. The teacher can easily find weaknesses in students' understanding the concept.

Both boys and girls are having the same learning ability at total achievement, knowledge and comprehension level.

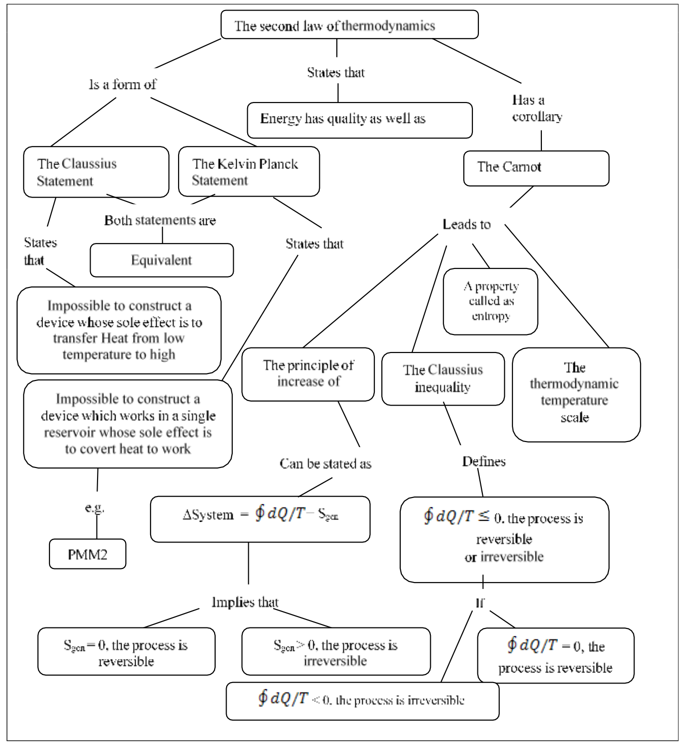

Figure 3. A well-developed concept map for the second law of thermodynamics by the teacher

The correlation between the thermodynamics total post test score and concept map score is moderate.The correlation at different cognitive level also very moderate.

XI. LIMITATIONS OF THE STUDY

One of the limitation of the study is that preparation of the concept maps is time consuming. This study was a pilot study. Future studies will be done to take a follow-up of the students on different domains and different topics.

XII. CONCLUSIONS

The current study used concept maps in the study of the second law of thermodynamics and investigated its impact at various levels of understanding. The results of the present study support the use of concepts maps in improving performance of the students. Concept maps identifies conceptual knowledge and can differentiate different levels of cognitive levels of understanding.

Concept maps have proven to be a valuable tool for teaching and learning. The pre- and post-test outcomes illustrate that concept maps contribute to a deeper comprehension among participants. The positive feedback received from students regarding concept mapping underscores its effectiveness.

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Conflicts of interest
There are no conflicts of interest.

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