Concept Mapping Instruction enhances Physics Achievement

(The Case of Mettu secondary and preparatory school, Ilu Ababora zone, Ethiopia)

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Abstract -The general purpose of the study was to examine the impact of using Concept mapping as instructional tool on students' physics achievement in Mettu secondary and preparatory school. It was designed as pretest-posttest nonrandomized control group. The same teacher employed concept mapping instruction in the Experimental Group (EG) and conventional learning method in that of Control Group (CG). Analysis with t- test and η^2 effect sizes showed that the impact of concept mapping instruction was more effective teaching method than that of conventional learning and the statistical difference between the achievement of male and female students who were taught with concept mapping was significant. Two-way Analysis of Variance (ANOVA) depicted that EG have higher scores, males have slightly higher score than females. The R square value indicates that approximately 59.1% of the total variance in the achievement of the students in dynamics of wave motion can be attributed to the specific teaching employed. This finding attested and urged secondary and preparatory school physics teachers for further implementation of concept mapping in actual classroom learning.

***Index Terms*:** Concept Mapping Instruction; Physics Achievement, Ilu Aba Bora Zone, Ethiopia

I. Introduction

Up to date reported data from plethora of researches at different levels realized the poor academic achievement of students in physics education to study as school subject/course in high school [1], and/or higher education [2] level. Back to some decades, researches have shown that conventional teaching methods have negative effects on the ability of learning physics for the majority of the students [3], [4].This erosion of low performance found to emerge as early as lower high school [1] to later result in compromising college enrolment [2]. In this regard, a number of factors have been identified to underpin the low achievement of students in science in general and that of physics in particular.

Recognizing the far reaching challenges, attempts have been made to bolster students' achievement in Physics. These, among others, include introducing innovative physics curricula [5], [6], and [2], use of student-centered teaching strategies and implementing teachers' in-service professional development [5]. These encompass introducing new learning experiences and methods of teaching including concept mapping to improve students' physics achievement [7] and learn physics beginning from early school years [2]; [6]. As a result, there has been considerable research attention [2]; [8]; [9]) as to the state of physics education in the western context namely, in Europe and USA. However, to date, little is known about the underlying factors that deteriorate physics achievement and aggravate disliking of studying physics among African students. Identification of the underlying reasons is of significance to widen our understanding of the problems related to physics education and uncover possible differences across cultures. Hence, the present study intends to capture these factors in African context taking Ethiopia as an example.

Recently [10], the need for competent human capital in science and technology in Ethiopia and the rising of developments urge to reform education policy. According to this policy, universities are expected to enroll 70% of their students in science and technology, of which, natural science stream taking about 40%. Experiences in 2008-2009, however, reveal that the pool of high school completers who would be eligible for university study has been insufficient. Most importantly, the majority of students assigned to study physics were blamed for lack of academic success due to low achievement [11], and low academic self-concept [12] even as compared to their counterparts assigned to Biology, Chemistry, and Mathematics [13]. The Ethiopian National learning assessments also showed that compared to other subjects students' performance in physics to be the least in all grade levels [14], [15]. Of course, many factors may influence students' performance. However, according to [16], one's teaching effectiveness may greatly increase depending on one's ability to make a choice of appropriate teaching method.

Recent research report from Ethiopia also confirmed the teachers' ignorance to implement student-centered instruction including other factors resulted students in poor physics achievement at higher institutions [17] and also at secondary school [18].

As early as 1970's pupil have steadily caused poor academic achievement on learning science education and in science related career [20] that initiated educators and psychologist towards more meaningful learning. As a result, David P. Ausubel developed an assimilation theory of cognitive learning; a theory from which other researchers developed models [21].

Ausbel's work became the basis for the work of Joseph Novak, who developed concept mapping at Cornell University in 1972 as a instructional tool to move away from rote memorization and regurgitation of facts towards more meaningful learning [22]. To engage in meaningful learning students must identify specifically relevant concepts and recognize no arbitrary relationships between the concepts [23]. The underlying technique involved is tying new knowledge to relevant concepts and propositions already possessed [24]. Concept mapping is a two-dimensional, hierarchical, node-linked diagrams that depict verbal, conceptual, or declarative knowledge in succinct visual or graphic forms [25];[26]. The fundamental component of every concept map is the concept (node). Concepts are defined as perceived regularities in objects or events that are designated by a sign or symbol [27]. They are generally isolated by circles and connected with lines (linking lines). These lines are labeled with linking phrases, which describe the relationship between the two connected terms. The smallest unit of meaning of the concept map must contain two concepts and a linking phrase which is then identified as a "proposition". The process of constructing a concept map is a powerful learning strategy that forces the learner to actively think about the relationship between the terms. This makes Concept Mapping instruction especially suited to studying science and/or physics as the learner may perceive that studying science means simply memorizing facts [28].

As a reaction to these aforementioned factors, Ethiopia needs a paradigm shift in education system from primary to higher level as already [19] reported that physics teachers should implement guided discovery with sufficient guidance to help students create, integrate, and generalize knowledge through constructivist problem solving by providing them with materials available in physics lab or locally prepared teaching materials. This study then devoted to look for possible means to enhance students' physics achievement at secondary school level through concept mapping instruction as a tool by action research approach.

This research was guided by the research questions:

1. Do sample students' average scores in physics differ significantly after receiving the intervention (concept mapping)?
2. What are differences between the average physics scores of males and females in the sample after receiving the interventions?

Based on these research questions, the following null hypotheses were formulated.

- H_{01}: There is no significant mean difference on the physics achievement between students in experimental group and control group.
- H_{02}: There is no significant mean difference on the physics achievement between male and female students in the experimental group

Accordingly, the general objective is to examine the impact of using Concept mapping as instructional tool on student physics achievement in Mettu secondary and preparatory school, Ethiopia. Along with this, the specific objectives are to

- Compare the relative effectiveness of concept mapping in improving students' physics achievement in wave motion, and
- Identify gender difference towards the methods and their corresponding improvement in wave motion.

II. METHODOLOGY

A. Research Design

A quasi-experimental research design, specifically nonrandomized pretest-posttest was used. This design is often used in classroom experiments when experimental and control groups are in their natural classroom setting which cannot be disrupted for the research purpose.

B. Population, Sample Size and Sampling Technique

The target population in this research was grade 9 secondary school students in Ilu Aba Bora zone, which is located at Southwestern part of Ethiopia in Oromia Regional State at 600km from the capital city, Addis Ababa. Purposive sampling technique was used to select Mettu secondary and preparatory school in the zone. The criteria for the selection were the availability of functional physics laboratory and matching number of students in a class. The sample sizes used in the research were 100 (M=55, F=45) out of which 50 (M=26 and F=24) for concept mapping (experimental group) and 50 (M=28 and F=22) for traditional method of teaching (control group).

C. Treatment Procedure

Step1: The two groups used in this study consisted of (a) Experimental group (students here used concept mapping as study skill) and (b) Control group (students here summarized content covered after review). Students in both control and experimental groups received extracts from grade 9 physics student textbook covering contents in the six-week instructional unit. They also received a list of concepts sheet for each week instruction a week prior to instruction. All the concepts on the list were copied directly from the contents of the six-week instructional unit.

Step2: Subjects in the experimental group were introduced to and trained on how to construct concept maps following the procedures [28]. For example, to create a concept map, start with what you already know. Build from what is familiar. What are the key components or ideas in the topic you are trying to understand? Place each concept in its own individual circle, box or other geometrical shapes. Connect concept boxes with arrows to show relationships. Label each arrow with descriptive terms so that your diagram can be read as a statement or proposition by following interconnections from the top down.

With these steps learned and internalized, the students practiced constructing several small concept maps prior to the six weeks instruction and learning.

Step3: A week before the commencement of instruction, the first semester results of both the experimental and control groups were taken as a pretest to determine the equivalence of the groups before treatment.

Step4: On treatment, for each instructional unit, the control group was asked to read the extract and construct a list of objectives, which include the concepts to be learned as a pre-instruction assignment. While the experimental group was asked to read extract and constructed a pre-instruction concept map. This was followed with both groups between 40-50 minutes pre-study instruction on concepts in the various week's instruction. After this, they did the study, and turned in assignments at the end of every week's instruction.

Step5: The control group used the concepts on the list of concept sheet and wrote a summary to show their understanding of the topics after review of learning extracts provided. The experimental group restructured their concept maps briefly during the class instruction and extensively as homework after each week instruction. This post instruction concept map constituted the experimental group's understanding of the concepts learned in the unit of instruction.

Step6: In building concept map for experimental group, the procedure given by [28] and the scoring rubrics of constructed concept map as of [29]; [30] were considered and followed.

D. Data collection instrument

Researcher developed physics achievement test (RDPAT) were used to collect data for both control group and experimental group for this particular study. The same posttests at the same time were administered at different time interval more than four times including final exam for students in both control and experimental groups in this quasi-experimental study design. Researcher developed physics achievement test (RDPAT) with internal consistency of 0.77 using Cronbach's alpha for pretest and 0.80 for posttest was used as data collection instrument in the study.

E. Method of data analysis

To determine the statistical significant students' achievement difference both in control and experimental group of pretest and posttest an independent sample t-test was applied. The magnitude of the differences in mean (effect size) in t-test was calculated using Eta squared. To investigate the effect of gender on achievement due to the employed method, Two-Way Analysis of Variance (ANOVA) was used.

F. Ethical consideration

Official permission from Mettu secondary school was secured. The teachers from physics department and two sections of grade 9 students consent were taken into consideration by approaching them.

III. Result and Discussion

A. Students' achievement difference before intervention

The result of the students' mean and standard deviation for pretest scores for experimental and control groups were shown in Table I.

Table I: Between-Subjects Factors

	Value Label	N
Group	CG	50
	EG	50
Gender	M	55
	F	45

Table II: An independent sample t-test for pretest score of the experimental group (EG) and control group (CG)

	Group	N	MD	SD	SEM	t
Pretest	CG	50	60.10	5.35	.76	.63
	EG	50	59.37	6.23	.88	

In Table I and Table II; N stands for the total number of students either in experimental group(EG), control group (CG), male(M) or female (F). MD stands for the mean difference between the groups; SD- is the standard deviation; SEM-is the standard error mean; t-test is used to compare the mean scores of two different groups of people or conditions. Accordingly, the mean score of the pretest for the experimental group was found to be 59.37, while that of the control group was found to be 60.10 out of a maximum possible score of 100. An independent sample t-test result showed that there were no significant differences between the two groups t = 0.63. Table II showed that there was no significant mean difference in the pretest scores of the control group and that of experimental group while the standard deviations in the two groups were consistently lower. There are a number of different effect size statistics, the most commonly used being eta squared. Eta squared can range from 0 to 1 and represents the proportion of variance in the dependent variable that is explained by the independent (group) variable. Statistical Package for Social Science (SPSS) does not provide eta squared values for t-tests unless using the information provided in the output. Now inserting the value of $n = n_1 = n_2 = 50$ and t= 0.63 from Table I into $\eta^2 = \frac{t^2}{t^2 + (2n-2)}$ equation, the value of eta squared (η^2) =0.004 which is small effect.

B. Hypothesis Testing

1. Effect of teaching methods on Students' achievement

H_{01}: There is no significant mean difference on the physics achievement between students in experimental group and control group.

Table III: An independent sample t-test for posttest score of the experimental group (EG) and control group (CG)

	Group	N	MD	SD	SEM	t
Posttest	CG	50	51.58	10.25	1.45	-11
	EG	50	74.58	9.54	1.35	

The effect size of independent sample t-test indicated in Table II for eta-squared can be calculated by inserting the value of $n = n_1 = n_2 = 50$ and t= -11 into equation and obtained $\eta^2 = 0.55$. The calculated value of eta squared (η^2) is large effect. An independent t-test was conducted to compare the posttest of the physics achievement of students after intervention in the experimental groups and those in control group. There was significant difference in scores of control group (M=51.58, SD=10.25) and experimental group (M=74.58, SD=9.54); t = -11. The magnitude of the differences in mean was very large (η^2 =0.55). This indicates that the concept mapping as instructional tool was more effective method than that of conventional teaching.

2. Effect of Gender on Students' Achievement in experimental group and control group

H_{03}: There is no significant mean difference on the physics achievement between male and female students in the experimental group and control group. A two-way analysis of variance (ANOVA) was conducted to investigate whether or not there were gender-group interactions.

Table IV: Descriptive Statistics

Dependent Variable: Posttest

Group	Gender	MD	SD	N
CG	M	52.21	10.10173	28
	F	50.77	10.62088	22
	T	51.58	10.25161	50
EG	M	76.61	10.25945	27
	F	72.20	8.20163	23
	T	74.58	9.53905	50
Total	M	64.19	15.91252	55
	F	61.72	14.30931	45
	T	63.08	15.18684	100

Table V: Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	SS	df	MS	F	Sig.	Partial Eta Squared
Corrected Model	13492.75[a]	3	4497.58	46.23	.00	.59
Intercept	392123.25	1	392123.25	4030.12	.00	.98
Group	12984.90	1	12984.88	133.46	.00	.58
Gender	212.17	1	212.17	2.18	.14	.02
Group * Gender	54.70	1	54.70	.56	.46	.006
Error	9340.61	96	97.30			
Total	420742.00	100				
Corrected Total	22833.36	99				

a. R Squared = .591 (Adjusted R Squared = .578)

Table VI: Estimated Marginal Means

Group * Gender

Dependent Variable: Posttest

Group	Gender	MD	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
CG	M	52.21	1.86	48.51	55.92
	F	50.77	2.10	46.60	54.95
EG	M	76.61	1.10	72.84	80.38
	F	72.20	2.06	68.11	76.29

Table VII: Pairwise Comparisons

Dependent Variable: Posttest

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	SE	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
CG	EG	-22.910*	1.98	.000	-26.846	-18.973
EG	CG	22.910*	1.98	.000	18.973	26.846

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table VIII: Univariate Tests

Dependent Variable: Posttest

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	12984.88	1	12984.88	133.46	.00	.582
Error	9340.61	96	97.30			

The F tests the effect of Group. This test is based on the linearly independent Pairwise comparisons among the estimated marginal means.

Profile Plots

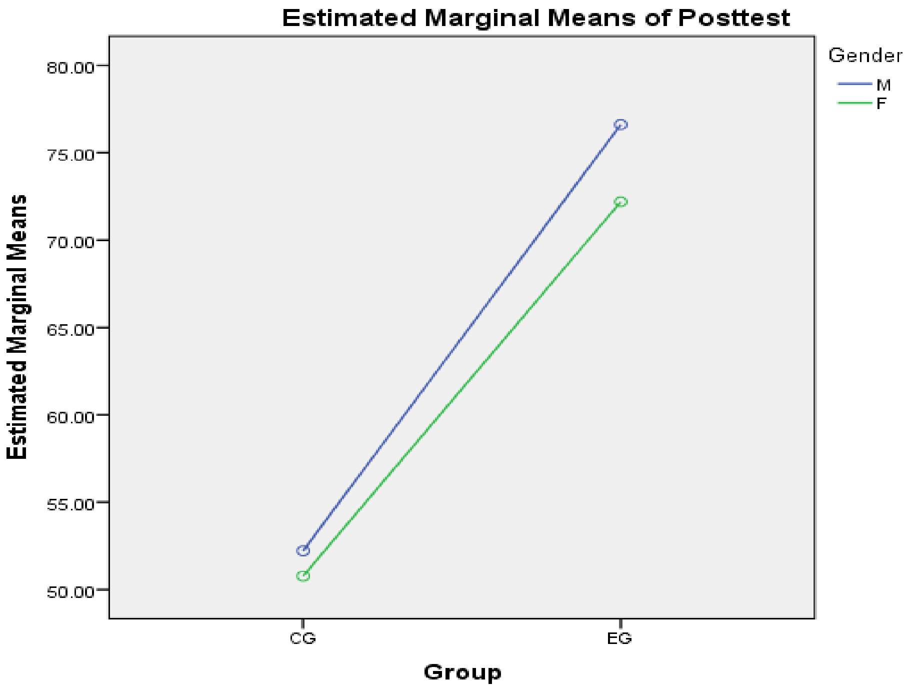

Figure 1: Effect of Gender on Students' Achievement in experimental group and control group

The results of the analysis conducted above(Table IV, Table V, Table VI, Table VII, Table VIII and Figure 1) could be presented as follows:

A two-way between-groups analysis of variance was conducted to explore the impact of gender and group on students' Physics achievement, as measured by the Physics Achievement Test). Table IV indicated that the statistical mean difference between EG (M=76.61 and F=72.20) and CG (M= 52.21 and F=50.77) was significant and the performance of EG was better than that of CG. Table V, Table VI, Table VII, Table VIII and Figure 1 respectively indicated the extent of employed specific teaching method attributed to students physics achievement and statistical significant main effect.

IV. CONCLUSION

The finding of this paper implied that the students' achievement difference before treatment were insignificant (Table II) as one could easily realize by using independent sample t-test and eta-squared(η^2) to measure the effect size which was lower. on the other hand, the implicatoin after treatment (Table III) opposed the former finding (Table I) for it was significant enough due to concept mapping implimentantion in experimental group. Table II indicated the total statistical mean difference between CG (MD=51.58) and EG (M=74.58). Regarding to gender interaction, Table IV and Table VI showed that the interaction between gender and group due to specific teaching method conducted were statistically significant; and male students (MD=64.19) performed slightly better than that of female students(MD=61.72).Two by two ANOVA (Table VII and Figure 1) indicates significant F value for the teaching method employed ($F=.56$, $p>0.05$) between academic achievement of male and female students in EG and CG. From Table V, R square value indicates that approximately 59.1% of the total variance in the achievement of the students in dynamics of wave motion can be attributed to the specific teaching employed.

Findings from comparable study [7];[26] in which concept mapping was used as instructional tool inline with this study is recommendable. For further implementation of concept mapping in the future and to enhance the enthusiasm of teachers in giving physics course; intensive training for the teachers is highly recommended to implement concept mapping not only in physics but also in other disciple principally in science and mathematics subjects /courses.

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