The effect of modeling instruction on students' achievement in mechanical work and energy

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Abstract

This study investigated the effect of modeling instruction on students' achievement in mechanical work and energy. The study was carried out on grade nine students at Ghion General Secondary and Preparatory School found in Bahir Dar town, Ethiopia. A total of 138(63 female and 75 male) grade nine students participated in the study. They were grouped randomly into control group (CG) and experimental group (EG). At the beginning of the treatment, both groups were given a pre-test to know their back ground performance. The pre-test result indicated that, the two groups were at the same performance level. The two groups were treated for two weeks independently. The CG was taught by the usual lecture method while the EG was taught by modeling instruction method by the same teacher. Finally, a post test was given for both groups and the post-test result was analyzed by *t*-test statistical analysis. The *t*-test analysis showed that, the students who were taught by modeling instruction achieved better result than those who were taught by the usual lecture method.

Keywords: Modeling instruction, lecture method, control group, experimental group, *t*-test.

Resumen

Este estudio investigó el efecto de la instrucción de modelado en los logros de los estudiantes en el trabajo mecánico y energía. El estudio se llevó a cabo con estudiantes de noveno grado en la Secundaria General en Ghion y en la Escuela Preparatoria que se encuentra en la ciudad de Bahir Dar, Etiopía. En el estudio participaron en total 138 estudiantes (63 mujeres y 75 hombres) de grado noveno. Fueron agrupados aleatoriamente en un grupo control (GC) y un grupo experimental (GE). Al comienzo del tratamiento, a ambos grupos se les dio una prueba previa para saber su rendimiento. El resultado antes de la prueba indicó que los dos grupos estaban en el mismo nivel de rendimiento. Los dos grupos fueron tratados durante dos semanas en forma independiente. El GC fue enseñado por el método habitual de clase conferencia mientras que el GE fue enseñado por el método de instrucción por modelado por el mismo profesor. Por último, se les aplicó una prueba posterior a ambos grupos y el resultado después de la prueba se analizó mediante un análisis estadístico de prueba *t*. El análisis de la prueba *t* mostró que, los alumnos que fueron enseñados por la instrucción de modelado consiguieron mejores resultados que aquellos que fueron enseñadas por el método habitual de clase conferencia.

Palabras-clave: Instrucción por Modelando, clase conferencia, grupo control, grupo experimental, prueba *t*.

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I. INTRODUCTION

The true purpose of teaching at any level is to bring fundamental changes in the skill and potential ability that lead to the improvement of the life of the learner. Such changes could be associated with economical, cultural and political development of the individual in particular and the society in general. Learning helps to transfer cultural heritage from generation to generation. In order to achieve the desired outcomes of an educational program, special care should be taken from the beginning of the design of the curriculum to its implementation. Teachers usually teach physics in classrooms by employing the usual lecture method at high schools and higher learning institutions. This teacher-centred method of teaching has negative impact on the students' understanding of the concepts of physics. This way of teaching doesn't consider the view of the students' to transform the concepts and improve their understanding of the subject matter. Therefore, other effective optional teaching methodology should be considered to overcome the problems and to enhance the achievement of the students on the subject matter in a simple and easy way by including different instructional methods and instructional materials to motivate the learning process. The instructional materials that are commonly used are the chalk board, text books, charts, models, posters, realia, and graphs in addition to the commonly available materials [1]. One approach that attempts to address the shortcomings of school science teaching is modeling instruction. Modeling instruction, as stated by Wells *et al.* [2] is a student –centered approach of teaching physics that allows students to experience authentically the scientific endeavors.

Hestenes *et al*. [3] had just completed their modeling theory of instruction, pedagogy based on modeling as the central activity of physical scientists and was working with a graduate student on a precursor version of the Force Concept Inventory (FCI). After administering the FCI to his high school students, Wells *et al*. [2] became disillusioned with their understanding of physics and determined that their teaching methodology was at fault. Expanding, Karplus' [4] learning cycle into a modeling cycle, Wells *et a*l. [2] incorporated computer into the classroom as a scientific tool to help students' understanding of physics. Students through an investigative context, invent basic kinematics and dynamic models including constant velocity, constant acceleration, equilibrium, constant net force and energy. Students use graphs, mathematical models, motion maps, system schema and energy bar graphs to represent these models. Furthermore, students use empirical observation as a basis to derive and validate all models and the locus of authority becomes how students interpret the physical phenomena rather than what the teacher says about it. "Such a learning atmosphere provides a context that allows students to experience the tentative, subjective and uncertain nature of scientific knowledge" [5].

Gilbert [6], suggests that, science should be redefined in the context of models, saying that "Science is a process of constructing predictive conceptual models. This definition unites both processes and product of science and identifies model building as a super ordinate process skill". Gilbert's results indicate that, while students understand that models contain errors and are human constructs that give an artificial representation of nature, students do not hold the same beliefs about scientific knowledge. By redefining science in the context of models, Gilbert argues that, students may understand better the nature of scientific knowledge. Modeling methodology approaches school science in this context [2].

When modeling instruction is used as a teaching method to effective teaching in the classrooms which invokes on students the same mental image as in the teacher, thereby making words more comprehensible or less ambiguous and providing a common starting point to get the classroom thinking along similar lines [7]. Physics can be characterized as a complex network of model interrelated by a system of theoretical principles. Models are units of structured knowledge used to represent observable patterns in physical phenomena. Accordingly, physical understanding is a complex set of modeling skills, that is, cognitive skills for making and use of models. The first target of physics teaching should therefore be to develop students modeling skills for making sense of their own experiences and evaluating information reported by others [8].

The decade (1980s') has documented serious deficiencies in traditional physics instruction. According to Hestenes [9], there is a reason to doubt that these deficiencies can be eliminated without extensive pedagogical research and development. The modeling of physics instruction has had arguably the greatest impact on high school physics instruction of any physics education reform. In spite of this, it has had negligible national impact on physics instruction at university level. This reality begs the question, 'Why should a valuable instruction be limited to high school physics?' A number of factors have come to bear on the situation. Hestenes [9] described modeling theory in "Toward a modeling theory of physics instruction". Traditional instructions such as lecture, recitation and laboratory involve little student interaction and follow a standard textbook [10]. These standard physics texts place strong emphasis on problem solving and often rely on mathematical constructions to explain underlying physical concepts [11, 12].

Because of this emphasis on mathematics at the expense of physical concepts, little conceptual improvement occurs in the students. Many researchers have implemented reforms to address the lack of students' conceptual understanding with varying degrees of success [10, 13, 14]. Some of these reforms depart radically from the traditional paradigm of instruction while others fit within the traditional framework. Examples of this latter type of reform include microcomputer-based laboratory [15], peer interaction during lecture [13] and interactive demonstrations during lecture.

Sokoloff & Thornton [16], made more radical reforms to include the switch to a studio classroom. Studio class rooms make no distinction between lecture and laboratory and usually meet in a block of two hours every session three times a week. Students work in groups and laboratories for this type of reform typically use microcomputer-based laboratory activities. All of the reforms mentioned above share the same goal *i. e*. increasing students' achievement.

The reform efforts mentioned are built on the premise that involve students more actively in their education and will increase their conceptual understanding [2, 13, 14, 15]. These reform efforts are based on the constructivist idea that students construct knowledge through interactions with each other and the instructor [17, 18, 19]. The modeling method is one such constructivist reform [2]. Even though, all these reforms have shown significant improvement in students' conceptual understanding, still better student conceptual understanding is required.

In spite of the fact that many researchers argue that, modeling instruction is more effective than lecture method for better achievement of students', because of several factors, it is difficult to say that the result could be the same everywhere in Ethiopia. Therefore, from the Ethiopian context and the researcher's day to day observations, usage of modeling instruction makes teaching methods more easy and productive since learners participate actively in the lesson and this participation develops interest, attention, positive attitudes and motivation of the students. Therefore, the main objective of this research is to compare the relative effectiveness of modeling instruction method with that of the usual lecture method.

II. METHODOLOGY

A. Design of the Study

The research design adopted for the study was a quasi-experimental design which consisted of independent and dependent variables. The independent variable was the type of instruction while the pre-test and post-test of students' scores were the dependant variables. Furthermore, a random sampling technique (a lottery system) was employed to group the two sections into a CG and an EG.

B. Population of Study

The target population of the study includes all grade 9 students of Ghion Secondary and Preparatory School which is found in Bahir Dar town, Ethiopia. A total of 1908 students were enrolled at this school in the 2008 academic year. This 1908 grade nine students were grouped into 27 sections by the school administration. Out of the 27 sections the researcher selected two sample sections by employing simple random sampling technique or lottery system for the study. The number of students used for this study was 138 and this number is 7.23 % of the total population of the students in the school. Out of the two sample intact sections, the number of students in the CG was 66 (27 female and 39 male) and the number of students in the EG was 72 (36 female and 36 male). The two groups were grouped randomly.

C. Instruments

The researcher used two instruments to collect the necessary data for the study. These were questionnaire and test. The questionnaire was used to assess the back ground information about the sample group. It was used to measure whether there was a significance difference between the two sample groups or not before the study treatment began. The tests were used to measure the students' performance before and after the treatment. In line with this, the researcher prepared a questionnaire which consisted of 20 multiple choice items each having four alternatives. The variables that were included in the questionnaire were age, gender, mathematical background and first semester physics result.

III. DATA ANALYSIS AND RESALT

The analysis and result of this study are explained in this section. The section is divided into three parts. The first part deals with the investigation of the background variables and pre-test results. The second part focuses on the achievement of post test results and its statistical analysis. The last part deals with the findings of the study.

A. Investigation of Background Variables and Pre-test

Here all the variables except the achievements that might have on the students' performance are categorized as background variables. Since we are interested in comparing the CG (that followed the traditional lecture approach) and the EG (that followed the modeling -student centred approach) in terms of the two groups achievement, we need to make sure that, the two groups are statically the same in terms of all the background variables. As the data on background variables are categorical, a chi-square (χ^2) test is employed to check the equivalence of the two groups. In addition to the other variables, a pre-test was administered in order to check the equivalence of the two groups. A t-test analysis method was employed to check whether the two groups (CG & EG) were significantly different or not on their pre-test and post-test results. The background questionnaire was developed by the researcher, research advisor and two pedagogy instructors. The questionnaire aims at assessing the background of the sample groups regarding their gender, age, first semester physics result and previous mathematical background. The result of the background analysis is given in table I.

TABLE I. Result of background analysis of sample groups.

No	variables	$\chi^2_{calculated}$	$\chi^2_{critical}$	Level of significance
1	Gender	1.14	5.02	0.5
2	Age	1.23	5.99	0.5
3	First semester Physics test result	1.68	7.82	0.5
4	Previous mathematical background	0	5.02	0.5

As indicated in Table I, all obtained values using the background information from the questionnaire, the calculated chi-square values (χ^2_{cal}) are smaller than the critical chi-square values (χ^2_{crt}) as read from the chi-square table. All these values show that there is no significance difference between the two sample groups with respect to the background variables.

B. Test

The researcher used a test to measure grade 9 students' performance in Mechanical Work and Energy. The test consisted of 20 multiple choice items each item with four alternatives. Eleven items were taken from standardized test called Force Concept Inventory (FCI), the researcher also developed nine additional items from grade nine Physics text book and various reference books on the basis of the curriculum and syllabus of Ethiopia. Some modifications were made to FCI in order to adjust with the Ethiopian curriculum context. The twenty multiple choice items were validated by the research's advisor, two physics lecturers from Bahir Dar University (BDU), three professional high school physics teachers and two graduate physics students at BDU. All their comments and corrections were incorporated into the final test.

C. Pilot Study

The researcher conducted a pilot study to identify the discrimination index, difficulty index, and reliability of the item. Before the pilot study was administered, the items were checked by the research's advisor, two professional teachers in Bahir Dar Academy, one professional teacher in Fassillo General Secondary School (both schools are found in Bahir Dar town, Ethiopia), three Graduate students in BDU and one Pedagogy instructor. The items revised to meet the format of the instrument and the existence of the correct answer. The pilot study was done in Fasillo General Secondary School. Fifty-five students participated in the pilot study. They were randomly selected grade nine students who have already learned the topic. The number of items which was administered in the pilot study was twenty. After the pilot study was conducted, the number of items was reduced to fifteen based on difficulty index and discrimination index as shown in Table II.

TABLE II. Item difficulty index and item discrimination power of each item in the pilot study.

Item	Difficulty index	Discrimination power
1	0.14	o.14
2	0.50	0.28
3	0.39	0.35
4	0.12	0.70
5	0.25	0.07
6	0.39	0.29
7	0.72	0.42
8	0.85	0.70
9	0.71	0.45
10	0.71	0.29
11	0.39	0.29
12	0.50	0.57
13	0.71	0.45
14	0.07	0.14
15	0.21	-0.14
16	0.67	0.5
17	0.71	0.43
18	0.39	0.35
19	0.36	0.43
20	0.46	0.64

D. Item Analysis of Pilot Test

Item analysis helps to determine the adequacy of the items within a test as well as the adequacy of the test itself.

The results of an item analysis provide information about the difficulty of the items and the ability of the items to discriminate between higher and lower scorer students. Item analysis describes the statistical analysis which allows measurement of the effectiveness of individual test items. It enables us to create more effective test questions and also regulates and standardized existing tests [21]. The components of item analysis are item difficulty, item discrimination and the effectiveness of a distracter. In this study, the data for the pilot study which was taken from the pilot test item administered at Fassilo General Secondary School was used to calculate the item difficulty and item discrimination.

E. Difficulty Index

Difficulty index is a measure of difficulty of each item in a given test. In case the calculation is based on difficulty index by taking the 27% of the high scoring group and 27% of the low scoring group, it will be the sum total of correct answers in the high and low scoring groups divided by the respondents. Usually, an average value between 0.3 and 0.9 difficulty index is acceptable [22]. Since it is difficult to control each item in this range, the average difficulty index was calculated and was found to be 0.45 as shown in table III.

TABLE III. Minimum, maximum and mean of difficulty index of the twenty multiple choice items in the pilot test.

Number of items	Minimum value	Maximum value	Mean
20	0.07	0.85	0.45

The difficulty of the items is calculated by using Statistical Package for Social Science (SPSS). As is shown in table III, the minimum, maximum and average difficulty index of the twenty items are found out to be 0.07, 0.85 and 0.45 respectively.

F. Discrimination Power

The discrimination power of each item indicates how well the item distinguishes between students who did well on the total test and those who did not do well. It measures the extent to which a single test item differentiates students who scored high in the test from those who did not score high. The scores are divided into three groups with the top 27% of the scores in the upper group and the bottom 27% in the lower group. The number of correct responses for an item by the low achiever group is subtracted from the number of correct responses from the item in the high achiever group. The difference between the correct numbers is divided by the number of students in either group. The process is repeated for each item. For a small group of students, an index of discrimination for an item that exceeds 0.20 is considered satisfactory. For larger groups, the index should be higher because more difference between groups would be expected. The guidelines for an acceptable level of discrimination depends upon item difficulty. For very easy or very difficult items, low discrimination levels would be expected. Most students, regardless of ability, would get the item correct or incorrect as the case may be. For items with a difficulty level of about 70%, the discrimination should be at least 0.30. According to Worten *et al*. [23], the discrimination power items are analyzed and given in table IV.

TABLE IV. Analysis of the discrimination power value of a given item.

Index of Discrimination	Item of Evaluation
0.40 and above	Very good item
0.30 to 0.39	Good item
0.20 to 0.29	Reasonably good item
0.10 to 0.19	Marginal item usually subject to improvement
Below 0.10	Poor item to be rejected or revised

TABLE V. Minimum, maximum and mean of discrimination power of the twenty multiple choice items in the pilot test.

Number of items	Minimum value	Maximum value	Mean
20	-0.14	0.70	0.32

The discrimination of the items was calculated by using SPSS. The results in Table V, show the minimum, maximum and mean discrimination index of the twenty multiple choice items.

G. Reliability and Validity of Test

Two issues of primary importance in any testing situation are test reliability and test validity. Test reliability refers to the consistency of measurement, the extent to which the results are similar over different forms of the same instrument or occasions of data collection. Another way to conceptualize reliability is to determine the extent to which measurements are free from errors. If an instrument has few errors, it is reliable and if it has significant number of errors it is categorized as unreliable. If a test is used to compare the performance of different groups, the reliability of the instrument is particularly important [24]. There are many methods of estimating the reliability of a measuring instrument. In this study, the researcher used Cronbach Alpha method to estimate the reliability of the instrument and it was found to be 0.72. Validity refers to the degree to which a test measures that it is intended to measure or more accurately, the interpretation of test scores and inferences drawn from test scores are appropriate and adequate [23]. The items were presented to the advisor, two physics teachers in Fassilo General Secondary School and two physics graduate students from BDU to ensure face and content validity of the test.

H. Teaching Procedure

A training of two hours on teaching using modeling instructions was given to the teacher involved in this research. After the training was conducted, the teacher continued to teach the EG using modeling instruction and the CG using the usual lecture method for two consecutive weeks. According to Hestenes [8], a typical modeling cycle requires at least two weeks, the first week for model development and the second week for model deployment. Then, the two sample groups were taught the same topic on mechanical work, energy, conservation of energy, elastic potential energy by their subject teacher. Using one Physics teacher for both CG and EG helped the researcher to control the ability difference of the teacher that may affect the outcome of the research. The only independent variable between the sample groups was the method of instruction. The CG was taught by the usual lecture method. During lecture method, the teacher employed the following steps. At the beginning of the class, the teacher checked the previous homework, gave some high lights about the new topics and illustrated with some examples. Finally, the teacher gave class work and homework.

The EG guides students through modeling cycles. During the first stage of modeling cycle, students observed a new phenomenon, identified variables, planned, conducted and analyzed the topic and presented the result. After the class has reached consensus about the results, the teacher guides the students to introduce a generalized model. After this the students prepare models using a deductive process and validate models in new situations through a peer-collaboration problem solving process. This modeling cycle gives students the opportunity to interpret observations, have discourse on the model and integrate the model into their knowledge structure. The students reported to the teacher orally or in written form. Finally the teacher asked different questions from different angles to check their level of understanding and gave concluding remarks.

I. Analyses of Pre-test Results

Before the beginning of the main study, a pre-test was given to the students on a particular topic of mechanical work and energy. The items were twenty multiple choice items each item with four alternatives. However, after conducting item analysis in terms of item difficulty index, discrimination index, validity and reliability, the researcher has rejected five items and administered to the students the remaining fifteen items for the pre-test. A total of 138 students were registered in the pre-test in the two groups. Out of the 138 students, 66 were from the CG and 72 were from the EG. The researcher used a *t*-test to check whether there is a significance difference between the CG and the EG on their pre-test mean score or not. The mean score showed that the two groups did not have significance difference in their pre-test mean score with $t_{\text{calculated}}$ (t_{cal}) value of -0.001 and t_{critical} (t_{crt}) value of 1.96 at p=0.05 level of significance difference with 136 degree of freedom and with two-tailed test.

Statistically, if t_{cal} is less than t_{crt}, there is no significance difference between the two sample groups [20].

TABLE VI. Mean score, standard deviation, t_{cal}, t_{crt} and degree of freedom of the pre-test result of the CG and EG.

Group	Number of students (N)	Mean score	Standard deviation (Std)	t_{cal}	t_{crt}	Degree of freedom (df)
Control	66	42.67	11.67	-0.001	1.96	136
Experi-mental	72	42.2	14.27			

As is shown in table VI, the achievements of students' mean score were checked by using an inferential statistical method of t-test with two-tailed *t*-test. As can be seen from the *t*-test result t_{cal} is less than t_{crt}. This implies that there was no statistically significance difference between the two groups. Therefore, the researcher showed that the CG and EG have the same background level in the pre-test result. The researcher used the pre-test results to show the change in the level of students' achievement due to the implementation of two different instructional methods, *i.e*. the usual lecture and modeling methods. As supportive evidence, the frequency distribution can be used to confirm the similarities between the two groups in terms of pre-test results.

TABLE VII. Frequency distribution of students' per-test scores of the CG and EG.

Score of	CG		EG	
	N	%	N	%
90-100	-	-	-	-
80-89	-	-	-	-
70-79	-	-	-	-
60-69	8	12.12	12	16.67
50-59	12	18.18	13	18.06
40-49	25	37.88	24	33.33
below 40	21	31.82	23	31.94

Table VII indicates that, the pre-test scores of the students in both groups are found to be in the range of 40-59. That is, the number of students in the two groups that lie in the range of 40-49 is nearly the same. This shows that, the two groups were at the same level of performance before the treatment began.

J. Analyses of Post-test Result

At the end of the treatment, the researcher gave a post-test for both the CG and the EG to investigate whether there is a difference in achievement or not due to the application of the modeling approach for the EG. The total number of students that took the post-test in the two groups was 129. Out of the 129 students 62 students were from the CG and 67 were from the EG.

TABLE VIII. Mean score, standard deviation, t_{cal}, t_{crt} and degree of freedom of the post-test result of the CG and EG.

Group	N	Mean	Std	t_{cal}	t_{crt}	df
Control	62	54.67	11.20	5.465	1.96	127
Experimental	67	65.67	11.00			

As is shown in table VIII, the achievements of students' were determined using t-test. The t-test result indicates that, t_{cal} (5.465) is greater than t_{crt} (1.96) at p=0.05. This implies that, there was statistically significance difference between the CG and the EG. The EG who have been taught using modeling instruction approach scored better in their post-test achievement than the CG who have been taught by the usual lecture method. As supportive evidence, the frequency distribution can confirm that, the difference in achievement between the two groups in terms of the post-test result.

TABLE IX. Frequency distribution of students' post-test scores of the CG and EG.

Score of	CG		EG	
	N	%	N	%
90-100	-	-	-	-
80-89	-	-	18	26.87
70-79	4	6.45	10	14.23
60-69	26	41.94	25	37.31
50-59	11	17.74	10	19.94
40-49	17	27.42	4	5.95
below 40	4	6.45	-	-

As can be seen from table IX, the frequency distributions of the post-test scores of the CG above 85% have a range from 40-69 while the EG 78% have a range from 60-89. This implies that students that were treated by modeling instructional method (student-centred) were higher achiever than those treated by employing the usual lecture method.

K. Average Normalized Gain

The average normalized gain (g) is required to measure the relative scores of the post test % - pre test % score of the sample group and some sort of weighing function that compares the scores of students before and after the instruction was implemented.

According to Hake [25], "the average normalized gain (g) is defined as the ratio of the actual average gain (post test% - pre test %) to the maximum possible average gain (100 % - pre test %)" and mathematically it is given by,

$$g = \frac{post\,test\% - pre\,test\%}{100\% - pre\,test\%},$$

where post-test % is the percentage scores after the instruction and pre-test % is the percentage scores before the instruction. The effectiveness of the instruction treatment for the CG and EG was assessed using an average gain which was calculated for each group. The post test%- pre test% and the average normalized gain is given below along with the average (mean) pre-test and post-test scores of the two sample groups.

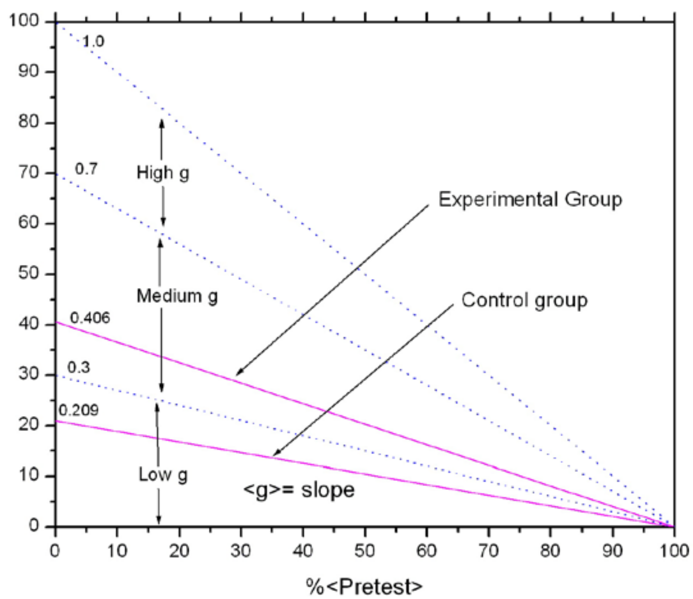

FIGURE 1. The %<Gain> versus %< pre-test> score for the CG and EG.

As is shown in table X below, the mean score and standard deviation of the control group were improved after they have been taught. Hake [25] divided the average gain value into "high-gain" score ($g \geq 0.7$), "medium-gain" score ($0.3 \leq g < 0.7$) and "low-gain" score ($g < 0.3$). Therefore, as can be seen from table X, the average gain values of the CG and EG are 0.209 and 0.406 respectively. Thus, the EG normalized average gain value (*g*) is in the medium score range whereas the CG normalized average gain value (*g*) can be classified under low score range. According to this finding, students who have been taught by the modeling method (EG) have better gain than those students who have been taught by the usual lecture method (CG). This difference in gain is observed due to the intervention of modeling instruction.

TABLE X. Mean gain of pre-test and post-test of the CG and EG.

Group	Mean pre-test(%)	Mean post-test(%)	Mean difference in %	Gain(*g*)
Control	42.67	54.67	12 .00	0.209
Experimental	42.20	65.67	23.47	0.406

IV. DISCUSSION

The result of this study shows that, the performance of the two sample groups was at the same level before the main study of this research was conducted. As can be seen from table X, by analysing an inferential statistical *t*-test, the two groups (*i.e.* the CG & EG) had not significance difference in mean scores during the pre-test. The pre-test result also provided us important information about the equality of the background of the students. Thus, the pre-test mean score indicated that, the two groups were at the same level of performance before the instructional methods were employed. The result of both the post-test and average normalized gain showed that there is a significance difference in achievement between the EG and CG. Students who have been taught by modeling instructional method (*i.e.* by student –centred approach) achieved better than those who have been taught by the usual lecture method. The achievement difference between the two groups was mainly due to the way students were engaged in the learning process. In the modeling instruction, students were forced to pass through different stages of modeling cycles, from model development to model deployment. During these cycles, they acquire procedural knowledge which is usually missed in the usual lecture method. In addition to this, the group activities, group discussions and group interactions provided them an opportunity to discuss their ideas with each other freely.

The result of this study is supported by different research outputs conducted at different places with different contexts. Malcolm *et al.* [26] investigated the effectiveness of modeling instruction over traditional and inquiry methods. The result they found confirms that modeling instruction has displayed a considerable improvement over inquiry and clearly superior to traditional methods. According to their result, the modeling method produced 23% greater than inquiry and 32% greater than traditional methods. Similarly, Ibrahim *et al*. [27] also supported the idea of modeling instruction [28]. In line with the result of this study, Vesenka et al. [29], made a comparison between scores of students in the modeling sections and the traditional counterparts and found that on an average, the modeling section achieved higher score than the traditional method. Other researchers conducted by Hestenes [8, 9, 30] also confirmed the result of the present study in terms of students' achievement.

V. CONCLUSION

Physics education research should aim at solving students' difficulties in learning physics and designing appropriate methods of physics instructions. In line with this, the researcher has made a survey in order to verify whether there is a positive effect of modeling instruction to enhance students' achievement in mechanical work and energy as compared to the traditional lecture method or not. The students' achievements in both approaches has been analyzed by employing the t-test and the average normalized gain factor (*g*). The outcome of the analysis indicated that, students who were taught by modeling instructional approach have higher achievement than those taught by lecture method. This difference in achievement is due to the method of instruction employed. Since modeling instruction is a student-centred approach and encourages students' participation throughout the teaching-learning process, it provides the students with better chance to achieve in modeling instruction than the usual lecture method. Here, it may be vital to mention that, since the number of participants in the sample is small, there may be limitation about the generality of this study.

Based on the finding of this study, it is recommended that further research work be done with a large sample size, adopt the modeling instruction in the teaching of various topics in physics and other science subjects in different grade levels. Researchers may extend the investigation also by taking additional variables like peer instruction and problem solving skills. This may help to show the strength of student–centred method of teaching-learning process which subsequently may offer some clue for policy makers to modify the teaching–learning process for better achievement of the learners.

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