Comparison of Teaching Methods in terms of Conceptual Understanding of Newtonian Mechanics: The Case of Fresh Man Students at Jigjiga University, Ethiopia

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Abstract

A research result comparing the effect of active learning and lecture based instruction with interactive approach, towards students' conceptual understanding and attitudinal change is presented. This work is inspired by the recent evidence of the success of interactive-engagement method integrated with lecture instruction to promote conceptual understanding. The design selected for this study was quasi-experimental. A total of 50 students took part in the study using available sampling techniques. Force concept inventory test (FCI), attitude questionnaires and interview were used to assess students' conceptual understanding of Newtonian mechanics and their attitude towards physics, depending upon the methods of teaching. FCI standard test were employed for the pre-test and the post-test to collect appropriate data of students' conceptual understanding of Newtonian mechanics. The pre-test was given just before the experiment began to test the equivalence level of the participants' prior to the treatment, while to investigate misconceptions of the students, post-test examination was given immediately after completion of the experiment. The finding of the study revealed that the experimental group students using interactive engagement methods of teaching group understand better and show positive attitude than those who were taught with traditional lecture method.

Keywords

Force Concept Inventory, Interactive-Engagement, Newtonian Mechanics, Traditional Lecture

Introductıon

A research in physics education has played tremendous role in the investigating of students' difficulties in learning, developing and analyzing new teaching methods. It has been growing rapidly and becoming a major field of research in physics (Hake, 1998a). Physics educational research outputs have already made a strong impact in changing the teaching methodology of many physics instructors.

There have been many educators, particularly those who work in the fields of physical sciences and mathematics, found to have problems of misconception in understanding topics involving physical phenomena. Misconception a Physics concepts occur among those who are graduates and Physics major. Thus in the effort of improving teaching methods, it is very important to explore and carry out research which can further investigate the level of misconceptions and teaching methodology.

Primarily, there are two types of teaching-learning strategies i.e. teacher centered and student-centered. The teacher-centered model includes three main teaching methods; demonstration, lecture and question and answer. The specific activities or instructional functions connected with such teaching can include a daily review, checking homework, presenting new contents or skills, set feedback and evaluation of students' performance. Student- centered (active learning) refers to techniques where students do more than simply listen to a lecture.

Engagement is seen to comprise active and collaborative learning, participation in academic activities, formative communication with academic staff, involvement in enriching educational experiences, and feeling legitimated and supported by University teaching communities (Coates, 2007). This definition suggests that engagement is the amalgamation of a number of distinct elements including active learning, collaborative learning, participation, communication among teachers and students and students feeling legitimated and supported. According to Hake (1998a), interactive engagement method as opposed to traditional lecture is achieved by questioning students or challenging them to think or to do something that requires thought. Students interact with each other, with the instructor as a coach or guide, or with guided materials created by the instructor (on paper or computer). A key ingredient is frequent and thoughtful interaction.

These methods are designed at least in part to promote conceptual understanding through interactive engagement of students' activities which yield immediate feedback through discussion with peers and/or instructors (Hake 1998a). Interactive engagement methods allow students to participate in class activities that teach and provide formative assessment. A considerable amount of attention is devoted to develop students' conceptual understanding before they start quantitative problem solving. Conceptual focus is achieved by utilizing the principle of concepts first (Van Heuvelen 1991, Gautreau and Novemsky 1997).

Although some educators consider the lecture method outdated and ineffective, it offers several advantages and reasons for its continued use. According to Adsit (2002), some points of traditional method (lecture) were discussed as follows: Today the lecture system is the preferred teaching style used by 89% of science professors (Timberlake, 2009). Indeed, lecture is a comfortable format for many instructors and an easy one for students. It is low cost, easy to control, and an excellent method for organizing course content. However, every teacher knows that during lecture, students are not actively engaged with the topic, they do not listen for very long time, and their retention of concepts is minimal.

In teaching physics, there is always a problem in making the concepts of each topic well understood. This arises not only because of the mathematical complexity of the subject (McDermott and Redish, 1999a), but also cognitive attitudes which can easily affect what they learn in an introductory physics course (Halloun and Herstenes, 1985b; Hammer, 1994). This study attempts:

1. To investigate misconceptions and conceptual understanding of Newtonian mechanics among first year physics students.
2. To examine how methods of teaching influence students' conceptual understanding of Newtonian mechanics.

Research Methodology

Description of the Study Area

Jigjiga University (JJU) is located in Jigjiga town the capital of Ethiopian Somale regional state. This town is currently serving as the capital city of the Somale regional state, located 628 km east of Addis-Ababa, close to the Somalia border. The official language is Somalia, but Oromiffa and Amharic are also spoken. JJU is one of the newly established Universities in Ethiopia with the mission to produce active, creative, knowledgeable, skillful and responsible citizen, who can actively participate in building the country.

Research Design

In this research, the design of the study was quasi-experimental involving two equivalent groups: experimental and control group. The experimental group was treated with the interactive-engagement method and the control group received traditional lecture method. Both groups were treated in similar ways except differences in the instructional approach, assuming other conditions are kept constant. To investigate the effectiveness of interactive-engagement and traditional lecture method in terms of students' conceptual understanding, and their attitudes towards the method of teaching; the study was carried out using topics of Newtonian mechanics. To reduce the effect of other uncontrollable variables, that might come from two different physics instructors, both groups were taught by the same physics teacher. Finally, after completing instruction, both experimental and control groups appeared for a post-test examination.

Sample and Sampling Technique

The subject of the study was all 50 first year physics students of JJU. They were grouped in to two equal categories using students' diploma cumulative grade point average (CGPA) and records of preparatory school. To test prior knowledge of the groups, pretest examination was conducted which is then named as experimental and control groups each constituting 25 students.

Data Collection Procedure

Relevant data for the study were collected using multiple instruments. Both qualitative and quantitative primary data were collected. Force Concept Inventory test, questionnaire and interview were used as primary data gathering tools. The overall procedures involved:

Pre-test: This is a test that was given to the two groups to check the prior knowledge of the students about the concepts of Newtonian mechanics and to verify the equivalence of the two groups in their previous knowledge about the given contents selected for study. Standard FCI test questions were used (Hestenes et al., 1992a).

Post-test: Standardized FCI test consisted of only multiple-choices to investigate students' conceptual understanding and misconceptions.

Attitudinal questionnaire: To assess the attitude of students towards physics, questionnaire of 16 items were administered adopted from Martha (1996) with some modification. The items were rated using five-point Likert-type scale ranging from Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. The 16 items on five (5) rating scale responses were respectively assigned value point of 5, 4,3,2,1 for positive statements and in reverse order for negative statements. The respondents were oriented to reason out their choice shortly.

Interview was conducted to investigate the components of attitude of the students about interactive engagement. In this part, using open-ended items, students were asked to give their opinions regarding interactive engagement. This instrument was administered to students after the program to get their opinions about interactive engagement.

Validity and Reliability of Force Concept Inventory

One of the well-known types of test which can be used for testing basic concept of Physics is FCI (Hestenes et al., 1992a). FCI is a multiple choice test designed to monitor students' understanding of the conceptual domain of force and related kinematics in Newtonian mechanics (Hestenes and Wells, 1992b; Halloun et al., 1995). Even though the FCI is a concept test of Newtonian thinking and requires no numerical computations, it does require some responses that compare two or more magnitudes. The test contains 30 conceptual questions about Newtonian mechanics). One of the purposes of FCI test is to evaluate the effectiveness of teaching methods by comparing the results of the test given before and after the instruction (Hestenes et al., 1992a).

It is important to undertake content validity and reliability of the FCI test to ensure the discriminatory capability of individual questions, derived from the concepts of Newtonian mechanics. It excludes problem solving and graph interpreting abilities. Despite these restrictions, the results of FCI have proved to be useful in comparing results from different groups, and improving instruction at introductory physics level (Hestenes and Halloun, 1995). As it is explained by Hestenes and Halloun, the FCI has a predecessor of the Mechanics Diagnosing Test (MDT) (Hestenes and Halloun, 1995). The MDT questions were designed around common misconceptions of the force concept. Initially the test was given in open answer form to introductory level college students. Then, a multiple choice test, FCI, version was created, which contained the most common open ended answer as choices. Therefore, the validity and the reliability that were established for the MDT are also valid for FCI. Thus, the validity of the test (FCI and MDT) measures the subject it is supposed to measure.

Method of Data Analysis

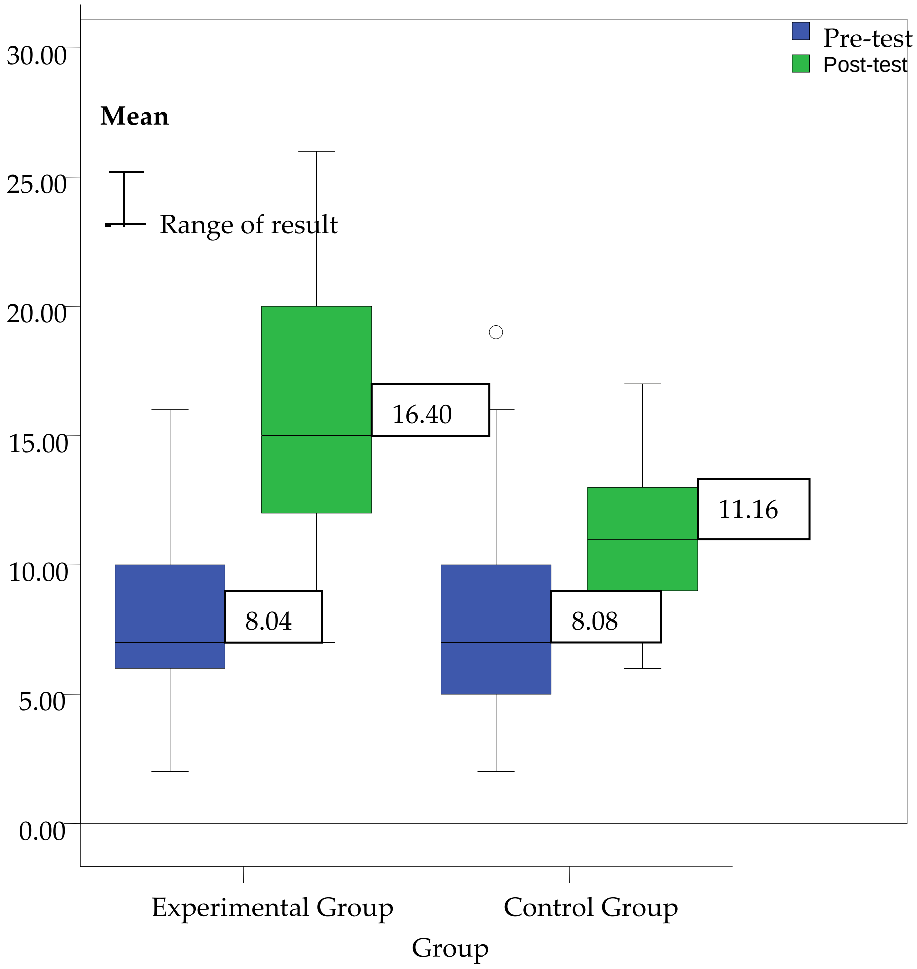
The quantitative data collected were coded, tabulated, analyzed, described and interpreted. The collected data were analyzed by employing to both descriptive and inferential statistics (Independent t-test). The data obtained from pre-test and post-tests were analyzed using descriptive and inferential statistics (SPSS of version 12) at α = 0.05 level of significance. It was used to determine the frequencies, percent, mean, and t-value and u- value. The data collected through interview was analyzed by using descriptive statistics whereas the data obtained from questionnaire was analyzed, using frequency distribution method while Mann-Whitney (u-test) tests its significance and the mean difference of the students' attitude score on the rated scale was compared by using independent t-test.

Results and Discussions

Test Results

The average score of the FCI of 50 first year Physics undergraduate students participating in pre-test of this investigation was 8.06/30 (26.87%) and the range of their scores between 2 and 19 (17).

Fig.1: The mean of pre and post test result of experimental and control groups



According to the data collected from the pre-test of the FCI scores, no students had a complete mastery of the most basic concepts at the beginning of the course; though with each student has had some background in Newtonian mechanics, having covered this same course previously at the high school and college. The same FCI test was also given after three months. At the end of the instruction the average score of the experimental group (instructed by interactive engagement method) was 16.4/30 (54.67%) with a standard deviation of 5.87 and the control group (instructed by traditional lecture method) was 11.16/30 (37.2%) with a standard deviation of 2.76. Thus, students taking mechanics course at JJU answered correctly the questions in the FCI at an average 54.67% and 37.2% of experimental and control group respectively.

The result demonstrated that in the experimental group only 32% students scored above the minimum level of understanding the Newtonian mechanics (Newtonian conceptual threshold which is 60% of the maximum score). Thus, the FCI results for 50 first year physics students showed that more than half of the students taking part in the study were incompetent to employ Newton's law to diverse circumstances and did not reach the minimum level of conceptual understanding of the Newtonian mechanics, during instruction. As reported by the designer of FCI diagnostic test, an FCI score of 85% is the Newtonian mastery threshold. So, in this investigation only 12% of students had developed such a level of conceptual understanding that can be considered as Newtonian thinkers as suggested by (Hestenes et al. 1992a) the diagnostic test. However; in the control group even if they had some basic knowledge about force concept, no one achieved the minimum level of conceptual understanding of Newtonian mechanics.

A number of researches have proposed a variety of teaching methods to overcome the problems. The methods generally induce a situation in which knowledge has to be constructed by the students themselves and should not be spoon-fed by the instructors. A survey (Hake, 1998a) supported this result i.e. involving students actively in the learning process helps to improve their conceptual understanding and eradicate misconceptions.

Analysis of pre-test

Table 1: Independent Samples t-test: Comparison of EG and CG based on Pre-test Results

Group	N	Mean	SD	MD	t	P	Df
EG	25	8.04	3.91	± .04	±.036	0.972	48
CG	25	8.08	4.03				

N=number students, P= probability, SD= standard deviation, df=degree of freedom, MD = mean difference, at α = 0.05 level

The mean score of students in the interactive engagement group was 8.04 (SD = 3.91), and the mean score of students in the traditional lecture group was 8.08 (SD= 4.03) at (t= 0.036, MD=0.04, p = 0.972 > 0.05). This shows that students in the two groups had no significant prior knowledge difference on the concepts of Newtonian mechanics. Results from the pre-test suggest that the two groups were equivalent with respect to their prior knowledge on the selected concepts. The groups were therefore suitable for the study when comparing the effectiveness of interactive engagement and traditional lecture method-based learning on students' conceptual understanding change in Newtonian mechanics.

Independent samples t-test: Comparison of EG and CG on the post-test results

Differences in conceptual understanding in the common topic tests between students that completed the interactive engagement methods of learning (experimental group) and those who completed traditional lecture method (control group) were investigated by using t-test. The t-test ($t = 4.04$, $p = 0.00 < 0.05$) confirmed that highly significant difference was observed between the experimental and control groups of students (Table II).

Table 2: Independent Samples t-test: Comparison of EG and CG on Post-test Results

Group	N	Mean	SD	MD	t	P	Df
EG	25	16.4	5.87	5.24	4.04	.000(**)	48
CG	25	11.16	2.76				

** The mean difference is significant at $\alpha = 0.05$ level, SD= standard deviation, MD=mean difference

The experimental group students scored better results on post-test than control group students (Table II). This result revealed that an interactive engagement method of learning enhanced students' conceptual understanding more than traditional lecture method. Hake (1998), has reported similar results in most cases. Thus the interactive engagement has potential benefits in improving students' conceptual understanding in physics than individualistic learning. Hake (2002b), suggested that students who received interactive engagement based courses can be much more effective than traditional lecturebased courses in enhancing conceptual understanding of Newtonian mechanics. This difference may be due to positive interaction, good engagement, organizing and practical work, pair discussion and integrating ability of their knowledge the Newtonian mechanics.

The mean gain of experimental and control group of students

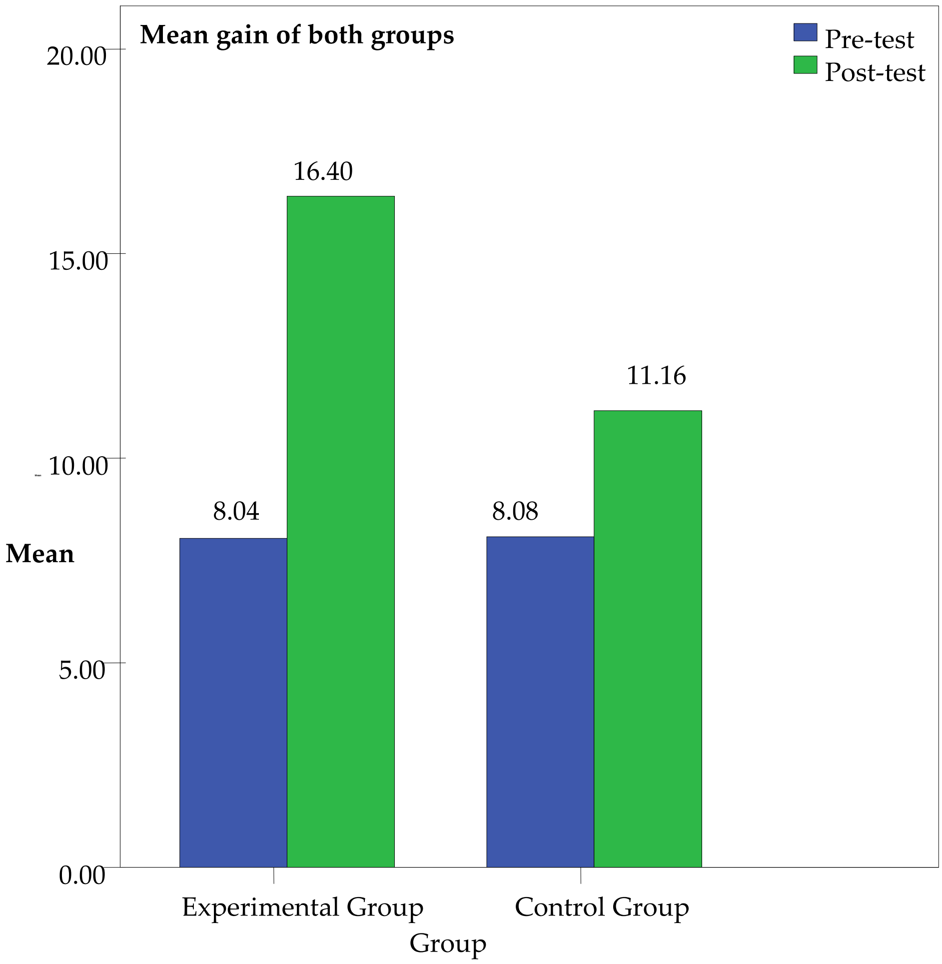
The comparison of mean gain was performed using interactive engagement methods and traditional lecture method of teaching.

Table 3: The mean gain of both groups of students

Group	Mean		The mean gain
	Pre-test	Post-test	
Experimental	8.04	16.40	8.36
Control	8.08	11.16	3.08

The mean gain by the experimental group students was found to exceedthe gain by the control group students(Table III). This signifies interactive engagement methods of teaching strategy helps students to understand the main concept better than those group taught using traditional lecture method.

Fig.2: The mean gain for pre and post test of both groups.



Furthermore, interactive engagement may become effective for high success too if they are encouraged to periodically check their activity during the learning process. Opinions were also forwarded that during learning by interactive engagement learners did feel responsibility not only for their own learning but also for their group members.

Interviews

After the completion of the program (interactive engagement method of teaching and learning strategy) an interview was conducted in order to investigate the students' opinions about interactive engagement method of learning behaviors, their activities in the classroom and to cross-check students` attitude towards physics. The administered interview questions have six items, which were conducted for the experimental group at the end of the program. Most of those interviewed responded to the question positively, so, this supports the statistical result that we got from the t-test.

Students' Attitude towards Physics

Table 4: Frequency distribution of students' attitude towards physics for both groups

No	Group	SA	A	N	D	SD	Mean	U-test
		f %	f %	f %	f %	f %		
		7	16	2	-	-		
1	EG	28	64	8	-	-	4.20	.000(**)
		1	3	9	6	6		
	CG	4	12	36	24	24	2.48	
		-	-	4	5	16		
2	EG	-	-	16	20	64	4.48	.000(**)
		5	7	6	5	2		
	CG	20	28	24	20	8	2.68	
		2	1	6	5	11		
3	EG	8	4	24	20	44	3.96	.001(**)
		9	6	3	4	3		
	CG	36	24	12	16	12	2.44	
		8	7	6	3	1		
4	EG	32	28	24	12	4	3.72	.013(**)
		2	6	7	5	5		
	CG	8	24	28	20	20	2.80	
		13	10	1	-	1		
5	EG	52	40	4	-	4	4.32	.000(**)
		4	6	6	2	7		
	CG	16	24	24	8	28	2.92	
		14	10	1	-	-		
6	EG	56	40	4	-	-	4.52	.000(**)
		4	7	6	2	6		
	CG	16	28	24	8	24	3.04	
		2	1	3	5	14		
7	EG	8	4	12	20	56	3.96	.000(**)
		11	5	3	3	3		
	CG	44	20	12	12	12	2.16	
		5	5	4	5	6		
8	EG	20	20	16	20	24	3.08	.513
		6	6	5	3	5		
	CG	24	24	20	12	20	2.80	
		12	7	3	1	2		
9	EG	48	28	12	4	8	4.04	.013(**)
		6	3	7	4	5		
	CG	24	12	28	16	20	3.04	
		7	7	5	2	4		
10	EG	28	28	20	8	16	3.40	.025(**)
		2	4	7	5	7		
	CG	8	16	28	20	28	2.56	
		6	7	4	3	5		
11	EG	24	28	16	12	20	2.72	.698
		7	7	4	3	4		
	CG	28	28	16	12	16	2.52	
		11	7	4	1	2		
12	EG	44	28	16	4	8	3.96	.000(**)

		2	4	7	4	8		
	CG	8	16	28	16	32	2.52	
		4	7	2	6	6		
13	EG	16	28	8	24	24	3.04	.004(**)
		13	7	2	1	2		
	CG	52	28	8	4	8	1.88	
		10	8	4	2	1		
14	EG	40	32	16	8	4	3.88	.005(**)
		4	3	6	7	5		
	CG	16	12	24	28	20	2.76	
		13	7	2	1	2		
15	EG	52	28	8	4	8	4.12	.002(**)
		4	5	6	7	3		
	CG	16	20	24	28	12	3.00	
		7	6	5	3	4		
16	EG	28	24	20	12	16	3.36	.036(**)
		4	3	3	5	10		
	CG	16	12	12	20	40	2.44	

SA=Strongly Agree, A=Agree, N=Neutral, D= Disagree, SD= Strongly Disagree and f=frequency α = 0.05 level

From the table, it can be concluded that students who are engaged with interactive engagement method have somewhat better positive attitude than traditional lecture method and a significant difference is obtained on each item (except items 8 and 11) as deduced by Mann-Whitney test (u-test). This confirms that interactive engagement method of teaching strategy promotes more positive attitudes towards the instructional experience than traditional lecture methodologies.

Moreover, it can be concluded the same statement comparing the mean score differences as presented below.

Table 5: Independent t-test comparison of mean scores on attitude rated scale towards Physics in both groups.

Group	N	Mean	SD	MD	T	P	df
EG	25	60.84	6.793	18.72	12.075	.000(**)	48
CG	25	42.12	3.734				

**MD=Mean difference, significant is at α = .05, SD=Standard Deviation,

As it can be observed from Table V, the mean scores of the students in the experimental group on the attitude rated scale was 60.84 (SD = 6.793) and the mean scores of the students in the control group on the attitude rated scale was 42.12 (SD = 3.734). The table conveys that there is significant mean difference between the students' score on the attitude rated scale towards physics (t = 12.075, MD =18.72, P = 0.000< 0.05). Based on the attitude rated scale for the experimental and control groups, the maximum total sum of the positive response scores for the statements with a traditional methods of teaching association in the rated scale is 49 and the minimum response scores of the student in interactive engagement method of teaching is also 49 (48 is neutral). The mean scores on the students' attitude show that those instructed by interactive engagement method of teaching have positive attitude whilethose instructed by traditional lecture method have negative attitude towards physics. The t-test results also support the results obtained above using frequency distribution and mean square differences.

Most reports on the reforms of teaching methods (Hake, 1998b) present the improvement in student understanding. Only a few (Sharma et al., 1999; Leslie-Pelecky, 2000; Steinberg and Donnelly, 2002; Scherr, 2003) discuss the student attitudes. Not all responses from students, however, are encouraging.

A significant number of students still prefer to be taught in traditional style even after they attended an "active learning" programme in an introductory physics course (Mottmann, 1999). In this research, somewhat more modified result was gained due to the combination of methods of teaching.

Conclusion

In this research a comparative analysis between interactive engagement and traditional lecture methods of teaching showed as there were significant differences between groups on the measured variables. The finding of the study revealed that the experimental group students using interactive engagement methods of teaching group understand better and show positive attitude than those who were taught with traditional lecture method. Moreover, students were not retiring to express their feeling, there was a positive interdependence among students, and the classes were democratic and had improved their level of conceptual understanding.Hence, they benefited in learning physics easily through interactive engagement method of teaching learning strategy.

Concerning the role of interactive engagement and traditional lecture methods of teaching and its effect on students' conceptual understanding of the force concept measured with the FCI has been explored. Thus, the results of this study lead to the conclusion that:

1. Effective instructions should be able to replace misconceptions with accepted principles in any subject matter.
2. Effective instructions should be able to promote conceptual change.
3. The fact that erroneous misconceptions are difficult to change and also explain the ineffectiveness of "teaching by telling" i.e. telling the learners to discard their ideas and replace them with others.

Based on the result obtained and the conclusions drawn, the following prominent recommendations were made

1. Course instructors in physics should put into practice the interactive engagement methods of teaching as often as it is necessary to tap its many advantages in maximizing students' educational outcome.
2. Physics teachers should arrange their laboratories and classrooms in such a way as to give room for effective interaction among students.

3. Interactive engagement method of teaching learning strategy should be used in teaching various concepts in physics in an introductory and in advanced courses.

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