The Effects of Student-Centered Approach in Improving Students' Graphical Interpretation Skills and Conceptual Understanding of Kinematical Motion

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Abstract
This study investigated the effect of student-centered instruction in improving students graphical interpretation skills and conceptual understanding of kinematical motion in Bistu Gebre Michael Catholic general and preparatory school found in Bahir Dar town of Amhara National Regional State, Ethiopia. A total of 77 (39 female and 38 male) grade nine students were involved in the study. The design adopted in the study was non-randomized pre-test and post-test control group design. The instrument used in gathering data for the study was background survey, Graphical Interpretation Skill Test (GIST) and Motion Content Test (MCT). Chi-square (χ^2) and t-test were used as statistical analysis. The internal reliability coefficient of the test was 0.73 using Kuder Richardson Formula-20 (KR-20). The result showed that student-centered instruction was found to be more promising in improving students' graphical interpretation skill and conceptual understanding of kinematical motion.

Keywords: Kinematics, student-centered approach, traditional approach.

Resumen
Este estudio investigó el efecto de los estudiantes-centrados en la mejora de sus habilidades, interpretación gráfica y la comprensión conceptual de la cinemática del movimiento en la escuela Católica, Bistu Gebre Michael en general y de preparación que se encuentra en Bahir Dar ciudad del Estado Regional Nacional de Amhara, en Etiopía. Un total de 77 (39 hombres y 38 mujeres) estudiantes de noveno grado participaron en el estudio. El modelo que se adopte en el estudio no fue al azar antes de la prueba y el diseño posterior a la prueba del grupo de control. El instrumento utilizado en la recolección de datos para el estudio, fue la encuesta de fondo, la interpretación gráfica de prueba de habilidad (GIST) y Movimiento de contenido de prueba (MCT). Chi-cuadrado (χ^2) y la prueba donde fueron utilizados como el análisis estadístico. El coeficiente de consistencia interna del test fue de 0.73 con Kuder Richardson Fórmula-20 (KR-20). El resultado mostró que la enseñanza en el estudiante-centrado fue establecida para ser más prometedores en la mejora de habilidades de los estudiantes, interpretación gráfica y la comprensión conceptual de la cinemática del movimiento.

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I. INTRODUCTION

The purpose of teaching at any level is to bring a fundamental change in the learner. Such changes may be in the form of acquiring intellectual skills, solving problems and inculcation of desirable attitudes and values. Teachers adopt different approach to help students to acquire Knowledge, skill and experience. Textbooks work example problems to illustrate concepts and principles, to demonstrate procedures, and to clarify points of likely confusion.

In the traditional approaches of education and training, the burden of communicating material rests on the instructors and students have little role in preparing, analyzing and evaluating. The traditional approach is a teacher-centered approach in teaching where students are more passive participants in the learning process. Students listen to the information, participate in limited discussion, take notes, and retrieve or recall the information for evaluation purposes. With the traditional approach, the focus is more on acquisition of information than on group driven problem solving. A wealth of evidence from Physics Education Research (PER) suggests that students who are taught physics by traditional methods fail to learn essential physics concepts. In line with this Hake [14] reported that traditional teaching approach is characterized by lectures requiring little or no active student involvement, labs with prescribed practical procedures and tests or exams emphasizing quantitative algorithmically solving procedure.

Over the past thirty years, many scholars advocated more flexible, student-centered teaching methods inspired by the concept of "discovery" learning and "active" or "autonomous" learning [12]. Hence, teachers at various grade levels have been applying the student-centred teaching approach for a variety of reasons: to promote the research and the thinking skill of the student [18], to give more responsibility for students in their learning and promoting interest and enjoyment in learning Physics [6], to shift the learning responsibility to students [27], to develop positive experience in learning physics to students [7], to promote conceptual understanding of students [14] and so forth.

The student-centered approach gives an opportunity to explore the connection between graphical interpretation skills and learning science concepts. Students can connect abstract concepts with concrete, kinematics experiences. Traditional approach instruction does not challenge but tends to re- enforce a perception of physics as a collection of facts and formulae. In line with this, Mc-Dermott [21] summarized from many studies in Physics Education Research (PER): Teaching by telling is an ineffective mode of instruction for most students. Students must be intellectually active to develop a functional understanding. Beichner and Saul [3] also found that students' ability to solve problems is improved, conceptual understanding is increased, attitudes are improved, failure rates drastically reduced (especially for women and minorities) and performance in follow up physics and engineering classes is positively impacted. In another study, the student-centered teaching approach was utilized to teach introductory physics to University students [31]. The results show that students are building a better understanding of the main physics concepts, are more successful at solving problems, and are generally on-task and communicating well during group activities.

Kinematics is one of the first topics taught in high school physics, mainly the concepts of motion including position, velocity, and acceleration with time. Kinematics deals about understanding of how to describe motion using precise concepts, graphical methods and mathematical equations. A graphical analysis approach allows students to visualize motion while working more directly with fundamental principles. Physics Education Research (PER) indicated that graphs of objects in motion are frequently used since they offer a valuable alternative to verbal and algebraic descriptions of motion by offering students another way of manipulating the developing concepts. Graphs are the best summary of a functional relationship.

Many teachers consider the use of graphs in a laboratory setting to be one of the important means for reinforcing graphical interpretation skills and developing an understanding of many topics in physics, especially motion. In line with these Ellis *et al*., [11] they developed a system of laboratories, activities, discussions and homework assignments that use learner-centered approach to teach kinematics through graphical analysis. Observation of these classes and anecdotal student accounts indicated that the approach was successful for increasing conceptual understanding of kinematics as well as increasing interest in study of physics. Kinematics concepts in physics expressed algebraically, and graphically. However, findings showed that students have trouble with motion graphs even when they understand the mathematical concepts [16]. Bowden *et al.* [4] showed that, problems become easier to solve in a quantitative manner, it becomes more difficult to differentiate among students on the basis of their level of understanding of basic concepts. Trowridge and MacDermott, [32, 33] in their study also showed that students have confusion the concept of velocity and acceleration.

Kinematics concepts in physics have been modeled graphically. Graphs of kinematics variables –position, velocity acceleration and time –are a staple of physics with mathematics. However, findings showed that students misinterpretations kinematics graphs are common among students. McDermott et al. [22], identified a number of common difficulties encountered by students in making connections between the kinematical concepts, their graphical representations and the motions of real objects.. Another study identified specific difficulties that students have with the graphical representation of a negative velocity [13].

In our country, different research findings on the implementation of student- centered approach of instruction revealed that teachers are very weak in using the approaches. For instance, research documented by the MoE [23], has shown that teachers in Ethiopia were weak at practical teaching using student-centered learning methods. Regarding to this point, in one of his articles entitled, "teachers' beliefs, knowledge and practice of learner-centered approach in schools of Ethiopia" Yalew [36] reported that the teachers be apt to employ frequently the traditional teacher-centered approach of teaching. Similarly, in his study on "Quality of teaching and learning in Ethiopian primary schools", Derebssa (n. d.) reported that, currently traditional lecture methods, in which teachers talk and students listen, dominate most class- rooms in the country. Other study on "Perceptions of Ethiopian teachers and principals on quality of education", the participant teachers were asked about the successful teaching strategies (*i.e.* how they ensure successful teaching in their classroom) and the most frequent answer given by the teachers was "by asking students to repeat what is discussed in the class." This finding correspond to the classroom observations which suggested that in groups and in classroom discussions students were frequently asked to find simple "correct" answers to questions rather than to analyze information, construct new knowledge, or communicate independently [1].

The purpose of this study was to determine which approach, student-centered or traditional, was the most effective in teaching high school students about kinematical motion: concepts and graphical representation as measured by which approach produces higher levels of students' achievement test scores, upon completion of the instructional unit. Experimentally treated students participate in the teaching-learning process by contributing problems, analyzing the factors associated with the problems, developing possible graphical representation to the problems, placing the approach into action in using graphical representations, and evaluating the results of the of the graphical representation. Whereas students treated by traditional teaching approach they are passive participant during teaching-learning.

II. METHODOLOGY

A. Design of the Study

The research design was a quasi-experimental research that consists of independent and dependent variables. The independent variables are student-centered and traditional (teacher-centered) instruction. The dependent variables are students' graphical interpretation skills and conceptual understanding of kinematical motion.

B. Population

The target population of the study was a grade nine high school students attending natural science class in Bitsu Gebre Michael Catholic General and Preparatory School found in Bahir Dar town of Amhara National Regional state, Ethiopia. The target population for this study consists of all grade nine students (*i.e*., a total of 77 and out of these 39 females and 38 males). The sample was divided into control and experimental groups randomly. One physics teacher also involved in this study during the teaching learning process.

C. Instruments

Graphical Interpretation Skills Test (GIST) and Motion content Test (MCT) and student's Information form used to generate data for the study. GIST items were taken from Test of Understanding Graphs-Kinematics (TUG-K) [2]. Non-graphing motion items were prepared from grade nine physics text by the researcher. The instruments were given to four experienced high school teachers, two University instructors to obtain their views in regarding appropriateness of objectives, language level, comment the item and match items to objectives. Moreover, pilot test has been conducted in order to calculate reliability, difficulty, index and discrimination index. The common method of calculating the reliability coefficient for multiple-choice instruments is Kuder-Rechardson 20 (KR-20) formula [20]. GIST and MCT test was piloted prior to the experiment with nine grade students at Bahir Dar Academy, the two schools (Bahir Dar Academy & Bitsu Gebre Michael Catholic) the test yielded 0.73 reliability coefficient for internal consistency using KR-20 formula. Tests having a KR-20 > 0.70 are generally considered to be reliable for group measurements. Table I shows the calculated value of reliability, difficulty, index and discrimination index for pilot test.

TABLE I. Statistical results of the pilot taken from grade nine Bahir Dar Academy students

Name of statistics	Possible values	Desired Value	Calculated value
KR-20	[0,1]	>0.70 for measurements of groups. >0.80 for individuals	0.73(for groups)
Discriminati on Index	[-1,1]	> 0.30	0.35 (average)
Difficulty Index	[0,1]	>0.30	0.58 (average)

D. Treatment

Experimental group treated by student-centered approach, and students are more active participant in the teaching–learning process. The teacher has got trainees how to deliver his lesson by using student-centered approach. Control group treated teacher-centered approach, specifically a more teacher-driven lesson, textbook problems solved by their teacher. The role of the student just they receive information from their teacher.

The collected data for the study were analyzed by using quantitative method. Specifically, Chi-square (χ^2) is adopted to investigate the difference between experimental and control groups in terms of their background variables. To investigate the difference within a group in terms of their achievement we used t-test. In addition, descriptive statistics was also applied to calculate their mean, variance and standard deviation.

III. DATA ANALYSIS AND RESULTS

The analysis and the results of this study were explained in three sections. The first section deal investigation of background variables and pre-test results. The second section presents the achievement of post-test with its inferential and descriptive statistical analysis. The last section deals with the findings of the study.

A. Investigation of Background Variables and Pre-test

Here all variables, except achievement that might have on students' performance are referred to as background variables. Since, we are interested in comparing the student-centered approach and traditional approach in terms of students' achievement. We need to make sure that these groups are not statistically different in terms of all background variables.

By administrating questionnaire with 7 items, we did investigations of the background variables. We have these items in such a way that a students could respond to each question by answering A, B, C, or D. we made a 2x2 contingency table by combining response of students with small frequencies and ignoring observations with zero frequency. Since our data on background variables are categorical, we have applied a chi-square (χ^2) test to check the equivalence of the two groups in terms of background variables. We have administered a pre-test on kinematics topic with fifteen (15) items, in order to check the equivalence of the two groups. The t-test analysis method applied to check whether the two groups are significantly different or not on their pre-test and post-test results.

B. Sex

A chi-square (χ^2) test for independent was performed to determine whether participants' sex contribution is significantly varying or not. As it is seen from Table II the test revealed that the two groups are not significantly different in sex, *i.e.* χ^2 (1, 77) = 0.1185, p > 0.05.

TABLE II. Application of chi-square (χ^2) for sex distribution of participant students.

Item	Experimental Group		Control group	
	Observed	Expected	Observed	Expected
Female	19	19.75	20	19.24
Male	20	19.24	18	18.75

C. Age

A chi-square (χ^2) test for independence was performed to determine whether participants' age distribution is significantly varying or not. Table III shows that, the two groups are not significantly different in age, *i.e.* χ^2 (1, 77) = 0.00018, p > 0.05.

TABLE III. Application of χ^2 for age distribution of participant students.

Item	Experimental		Control	
	Observed	Expected	Observed	Expected
13-15	35	34.95	34	34.05
16-18	4	4.05	4	3.95

D. Students' Preparation

How students' feel in terms of the preparation to the topic of kinematics may affect their performance. Therefore, it is vital to check the experimental group and control group in terms of this variable. We have presented that two groups and Table IV the summarized data on how students feel in terms of preparation for physics subject.

We have then used χ^2 test to check the difference between the two groups in terms of feelings of preparation. The χ^2 test result showed that the two groups did not differ significantly on how well they feel prepared for physics subject, *i.e.* χ^2 (3, 77) = 3.5685, p > 0.05.

TABLE IV. Application of χ^2 for students' feels in terms of preparation in physics.

Item	Experimental		Control	
	Observed	Expected	Observed	Expected
Very well	27	26.34	25	25.66
Prepared	7	7.09	7	6.9
somewhat	5	4.05	3	3.95
Unprepared	0	1.52	3	1.48

E. Previous Experience in Physics and Repeating Physics subject in High School

Previous knowledge in physics may affect students' performance. It is vital to check the previous physics taken by the students and repeating physics subject in high school respectively. As we see from Table VI only three students repeated this subject.

We have applied a χ^2 test by considering responses of students with non zero frequency. Table V and VI results showed that the two groups are not significantly different in previous experience with physics and repeating the subject in high school, *i.e.* χ^2 (1, 77) = 3.03947, p > 0.05.

TABLE V. Application of χ^2 for students' physics background survey.

Item	Experimental		Control	
	Obser ved	Expected	Observed	Expected
Yes, in Junior school	36	37.48	38	36.52
Yes, in Junior and high school	3	1.52	0	1.48

TABLE VI. Application of χ^2 for number of students' repeated the physics subject in high school.

Item	Experimental		Control	
	Observed	Expected	Observed	Expected
No	36	37.48	38	36.52
Yes	3	1.52	0	1.48

F. Previous Mathematics Background

Students mathematical background may affect their performance in physics. From Table VII we can see that there is no significant difference between the two groups in terms of previous mathematics class. We have used a chi-square test to analyze responses of students' school mathematics experience. This result shows that there is no significant difference between the two groups in terms of mathematics subject that they have taken in their junior schools, *i.e.*, (χ^2 (3,77) = 0.4693, p > 0.05).

TABLE VII. Application of χ^2 for students' mathematics background survey.

Item	Experimental		Control	
	Observed	Expected	Observed	Expected
algebra	2	2.03	2	1.97
Geometry	5	6.08	7	5.92
Algebra & Geometry	32	30.89	29	30.1

G. Students' Study Time

Students were asked to respond to the question how much time outside of their class they expect to spend in studying physics subject. A significant difference in students' study time between the two groups could bring a significant difference in their achievement. The test result seen in Table VIII shows that the two groups are not significantly different in study time, *i.e.*, (χ^2 (3, 77) = 0.4356, p > 0.05).

TABLE VIII. Application of χ^2 for students' study time allotment for physics.

Item	Experimental		Control	
	Observed	Expected	Observed	Expected
Less than 2 hours per week	3	3.54	4	3.45
2-5 hours per week	14	14.69	15	14.31
6-10 hours per week	7	6.58	6	6.42
10-15 hours per week	15	14.18	13	14.18

H. Background Knowledge of Kinematics (Pre-test)

Participant students were tested questions on kinematics topic. The questions were 15 multiple choice items 10 drawn from grade nine physics text and the rest 5 from TUG-K [2]. A test was used to see whether there is a significant difference between the two groups on their pre-test results or not. Table X showed that the two groups do not have statistically significant difference on their pre-test results, *i.e.*, (t (75, 77) = 1.433, p > 0.05 with significant level of alpha (α) = 0.05.

TABLE X. Summary of pre-test achievement according to treatment of student-centered and traditional instruction.

Group	N	Mean	Std	df	$t_{calculated}$	$t_{critical}$
Experimental	39	6.87	2.067	75	1.433	1.980
Control	38	7.03	2.365			

I. Achievement of Post-test

In order to assess the effectiveness of implementing student-centered and traditional instruction within our one-dimensional kinematics, we administered pre and post assessments to both groups. In addition to this measurement, we also administered background information survey questionnaire. We have examined groups' achievement different in the post-test score and gain.

Our research question was **Is there a difference in physics achievement of ninth-grade students according to the treatments of student-centered or traditional instructions?** To answer this research question, we have measured students' achievement on conceptual understanding and graphical interpretation skills. The data was analyzed using two-sample t-test. At the end of the treatment, 15 questions were given to all 77 students. As we see from Table XI students in the traditional instruction group received lower scores than those in the student-centered instruction group, *i.e.*, (t (75, 77) = 2.863, p < 0.05).

TABLE XI. Summary of post-test achievement according to treatment of student-centered and traditional instruction.

Group	N	Mean	Std	$t_{calculated}$	$t_{critical}$
Experimental	39	10.2	2.23	2.863	1.980
Control	38	8.5	2.73		

K. Average Normalized Gain

We used average normalized gain (g) as a measure of the relative score and that is some sort of weighing function that compares the scores of students before instruction and after instruction [14]. Here we shall denote average normalized gain by (g) and mathematically it may be given by:

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

Where post-test % represents the percentage score after the treatment and pre-test % represents the percentage score before instruction

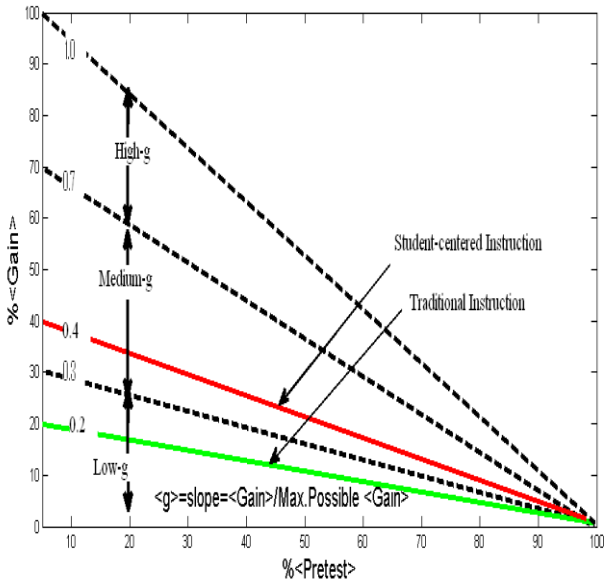

FIGURE 1.The %<Gain> versus %<Pretest> score for total of 77 sudantes..

Hake [14] divided average gain values in to "high-g'' score (<g> ≥ 0.7), ''medium-g'' score (0.7> <g> ≥ 0.3) and ''low-g'' score (<g> < 0.3). FIGURE 1 showed that the gain of student-centered instruction and traditional instruction on Graphical Interpretation Skills and Conceptual Understanding of Kinematical Motion using the above equation is 0.4±0.14 (Standard deviation) and 0.2±0.54 (standard deviation) respectively. As it is seen from the FIGURE 1, average normalized gain for student-centered approach is in the bottom part of medium-g region. This implies that in this finding student-centered approach is not over taken hundred percent the traditional approach even though we have promising academic achievement of students. Table XII shows that the summary result of our investigation and we see that students with student-centered instruction have better gain than students with traditional instruction.

TABLE XII. The difference between pre-test and post-test with in a group in terms of gain.

Group	Pre-test	Post-test	Gain
Experimental	45.8	68	0.4
Control	46.87	56.67	0.2

IV. DISCUSSION

We examined the effect of student-centered approach and traditional instruction in improving students' Graphical Interpretation Skills and Conceptual Understanding of Kinematical Motion.

Before the treatment, we administered the background survey to students in the experimental and control groups to determine whether the groups differed with respect to the background variables or not. The chi-square (χ^2) test results showed that, no significant difference in their background variables between the two groups exist. Moreover, we administered pretest to students in the experimental and control groups to determine whether the groups differed with respect to the achievement of pretest, and the t-test analysis of the results revealed that, no preexisting difference between the two groups regarding students pretest achievement, ($t(75, 77) = 1.433$, $p > 0.05$). Determining the similarity between the students in the experimental and control groups regarding background variables and pretest score were a good starting point for the treatment. .

The result of the study indicated that, there was a significant difference in the academic performance of students taught using student-centered method and those taught by the traditional method. The result of gain analysis showed that 0.4 of the total gain in academic performance of students in improving Graphical Interpretation Skills and Conceptual Understanding of kinematical Motion is attributed to the effect of student-centered instruction. The t-test ($t(75, 77) = 2.863$, $p < 0.05$) analysis showed that the student-centered instruction is more effective in improving students' Graphical Interpretation Skills and Conceptual Understanding of kinematical Motion. Descriptive analysis of the students' post-test mean was 10.2 out of 15 questions. It was high with respect to pretests findings which was only 6.87. During the treatment period, it was observed that, students in the experimental group were actively participating than those in the control group. In the normalized gain (<g>=0.4) score of student-centered instruction twice larger than the gain (<g>=0.2) of traditional instruction.. From this study, we can deduce that student-centered instruction appears to be promising but not sufficient hundred percent for marked improvement over traditional instruction

The finding of this study agrees with the findings of Saul et al. [31], students build a better understanding of the main physics concepts at solving problems, and are generally on-task and communicate well during group activities. This study is also in line with the findings of Hake [14] that the use of interactive engagement strategies can increase mechanics- course effectiveness well beyond that obtained with traditional one.

Hake [15] surveyed 62 introductory physics courses including 6542 student. His survey used a pre and post-tests to assess students' learning from these courses. He also collected data on teaching methods used to be able to compare the outcomes of different teaching methodologies. Hake's findings support that active teaching methods (described as "interactive engagement methods" in his study) generally produce greater student learning and develop stronger problem solving skills than traditional methods. Furthermore, a study conducted by Ellis & Turner [11] on learner-centered approach to teach kinematics through graphical analysis argued that this approach was successful for increasing conceptual understanding of kinematics as well as increasing student interest in the study of physics which is consistent result with this study.

V. CONCLUSION

The sample of the study consisted of all grade nine students found in Bitsu Gebre Michael Catholic general and Preparatory school. Since the number of participants is small, there is a limitation about the generality of this study The students achievement in both approaches,, has been analyzed by using t-test and average normalized gain factor, and the result showed that student-centered instruction appears to be promising but not sufficient hundred percent for marked improvement over traditional instruction .

This study has briefly surveyed the effectiveness of student-centered instruction in improving students' graphical interpretation skills and conceptual understanding of kinematical motion. Based on the findings of this study, the outcome of student-centered instruction compared with traditional instruction was found to be significant in the students graphical interpretation skills, understandings of kinematics concepts and elimination of misconceptions are more enhanced than traditional instruction. Finding also showed the achievement of the student-centered group was found to be better than that of the traditional group. In short, when student-centered instruction is used, it is highly probable that these cause significantly better understandings of scientific conception and elimination of alternative concepts. In summary, there is considerable evidence collected by researchers in physics teaching and learning that traditional instructional methods, largely lecture and problem solving, are not effective methods for promoting student learning in physics [14,3, 21]..

Based on this study finding, it is expected further research work to replicate this study with a larger sample size. The sample size in this study was limited to 77 students. Sample size is one of the most important factors that may affect the results. A larger sample size from a broader population may give a better understanding of the relationships between the variables of this study. This study was limited to a Bitsu Gebre Michael Catholic general and Preparatory school that is found in Bahir Dar Town of Amhara National Regional State, Ethiopia. The replication of this study with different types of schools (e.g. public schools, and private schools) may give different results.

The final suggestion for further research is to look for the effects of student-centered instruction in different physics topics, different science subjects and different grade levels. This may help to reveal the strengths of student-centered teaching learning process as well as provide more information for modifying the teaching design for better fit to the contexts.

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