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The effect of dialogic-practical work on secondary school students mechanics achievement

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Abstract: This study aimed to examine the effects of dialogic-practical work on secondary school students‘ mechanics' achievement. It also examined whether the students‘ mechanics achievement would vary with achievement levels. A quasi-experimental pre- and post-test research design was used. The study participants were 91 students from two secondary schools in Bahir Dar town, Ethiopia. The treatment group conducted dialogic-practical work and the comparison group carried out recipe-based practical work. A 25-item Mechanics Achievement Test was used for data collection. A paired- and independent sample t-tests were performed to analyze the data. It was found that there was a statisitcally significant difference in mechanics achievement between the dialogic-and recipe-based practical work groups, t (76) = 7.80, $p < .001$, d= 1.76. It also indicated that the dialogic-practical work resulted more improvements in mechanics achievement of the different achievement levels as compared to the recipe-based practical work. This suggests that students who engaged in dialogic practical work enhanced their mechanics achievement more than students who simply follow prescribed recipes. It is important to raise physics teachers’ awareness about the benefits of dialogic-practical work to enhance students’ mechanics' achievement.
Keywords: dialogic-practical work; mechanics achievement; recipe-based practical work; secondary school students

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Introduction

The active involvement of a scientifically and technologically knowledgeable citizenry is required to solve the challenges facing humanity today (Agube et al., 2021). In this regard, science education should focus on producing a scientifically literate populace capable of using their knowledge to make an informed decision about products of science and technology in everyday life; with the ability to interpret public debates and to make (more) thoughtful judgments on controversial socio-scientific issues (Irungu et al., 2019; Uchenna, 2021). Science education should equip students with knowledge, skills, and attitudes that will enable them to live meaningful and fulfilled life by contributing positively to the development of society. Many countries across the globe, have recognized the importance of promoting students' achievement in science. For this reason, several countries embarked on programs to support the development of science education at secondary and higher education levels (Gbre-eyesus, 2017; Naser, 2018).

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However, the expectations have been rarely met due to students' poor performance in school sciences (Diana et al., 2020; Goshu & Woldeamanuel, 2019). In many countries, the performance of students in physics had persistently remained poor in most schools (e.g., Adonu et al., 2021; Agube et al., 2021). In Ethiopia, students' performance in physics is the least compared to other subjects (Ministry of Education, 2017; Teferra et al., 2018). Most studies concluded that the teaching method adopted by teachers is the major factor responsible for students' poor achievement (Agube et al., 2021; Diana et al., 2020). The conventional lecture method commonly practiced in teaching physics has failed to address the requirements of contemporary students. This strategy limits teachers from disseminating information without the active participation of the students (Gbre-eyesus, 2017; Irungu, 2019).

Practical work is one of the suggested strategies in secondary schools to enhance students' conceptual understanding of science concepts and theories. In this regard, several researchers have employed practical work in secondary schools to address the deficits in students' performance (Radulović et al., 2016; Shana & Abulibdeh, 2020). However, there is lack of consensus about the type of practical work that should be applied to develop students' mechanics achievement. Some studies showed that recipe-based practical work has improved secondary school students science achievement compared to the traditional lecture method of teaching science (e.g., Shana and Abulibdeh, 2020). While most literatures argued that a recipe-based practical work approach had little effect on promoting students' achievements (Baloyi, 2017; Holmes et al., 2017). This approach hardly helped students to achieve the objectives of the physics laboratory courses (Vilaythong, 2011; Sani, 2014).

Hence, there is a need to develop effective practical work strategies that can maximize students' achievement. This can be achieved by preparing a laboratory task that gives students the chance to discuss, write about, reflect on, relate, and apply what they are learning. Indeed, some scholars applied hands-on and minds-on activities (Ateş & Eryilmaz, 2011) and inquiry-based experiments, and interactive computer-based simulations (Radulović et al., 2016) to foster students' physics achievements. These scholars found positive outcomes in students' achievements compared to the traditional lecture method. Contrarily, Baloyi (2017) found that implementing explicit reflective guided inquiry practical activities did not improve students' achievements' compared to the recipe-based practical work. Despite the positive results on students' mechanics achievement following inquiry-based learning, scholars argued that inquiry alone does not provoke the construction of meaning (e.g., Walker et al., 2019). In line with this, science curriculums and reform documents put forth a new set of directions to integrate science content and scientific practices (NRC, 2012). Some authors suggested that applying dialogic teaching in physics laboratories has the potential to attain better educational outcomes (Alexander, 2018; Andersson & Enghag, 2017). A crucial aspect of dialogic teaching is giving students a voice and allowing them to argue based on facts.

Recently, some empirical studies have demonstrated the feasibility of applying dialogic teaching in laboratory rooms to improve students' achievement (Demircioglu & Ucar, 2015; Walker et al., 2019). For example, Demircioglu and Ucar (2015) examined the effects of applying argument-driven inquiry-based laboratory instruction on the academic achievement of pre-service science teachers. They found that applying an argument-driven inquiry improved pre-service science teachers' academic achievement with a big effect size regarding geometrical optics compared to traditional laboratory instruction. On the other hand, Walker et al. (2012) found that applying an argument-driven inquiry instructional model in introductory college chemistry did not enhance students' conceptual understanding compared with a more traditional practical work approach. Though, inconsistent results were revealed, these studies were limited to college-level laboratory courses. Hence, there is a shortage of literature on the impacts of applying dialogic teaching in physics laboratories on secondary school students' physics achievements.

Furthermore, most often students having low achievement levels are not favored by instructional approaches applied in physics classrooms. Whereas other scholars claimed that the medium achievement levels are mostly excluded by the teachers compared to the low and high achievement levels (Buchs et al., 2015). As a result, researchers investigated the extent to which various instructions would benefit students with different achievement levels (Buchs et al., 2015; Gambari &

Yusuf, 2016; Yaduvanshi & Singh, 2019). Buchs et al. (2015) found that students at all levels progressed from the baseline test to the post-test, however, the highly structured cooperative learning resulted in the medium achievement levels to progress more in understanding of the trageted task. On the other hand, Eshetu et al. (2017) indicated that the cooperative learning method benefited the low achievement levels more than the high achievement levels.

Similarly, Han et al. (2015) found that students who participated in Science, Technology, Engineering, and Mathematics project-based learning activities resulted in low-performing students showing statistically significantly higher growth rates on mathematics scores than high and middle-performing students. However, Gambari and Yusuf (2016) found that the computer-assisted Jigsaw II cooperative setting benefitted the high, medium, and low achievement levels with a significant difference amon them. Likewise, Yaduvanshi and Singh (2019) revealed that students taught by the cooperative learning strategy resulted in low, medium, and high achievement levels outperform the conventional comparison group. These studies differed in the effectiveness of innovative teaching strategies in fostering students' achievement. In addition, benefiting the low-achievement levels to a greater extent and decreasing the achievement gap is still a challenge in most secondary physics classrooms.

Additional empirical studies showed that students had difficulties to comprehend mechanics topics irrespective of achievement levels differences (Bani-Salameh, 2016; Husin et al., 2019). Husin et al. (2019) found that Afghan school and university students have a poor conceptual understanding and possessed many misconceptions about Newtonian mechanics. These scholars added that, despite, the Afghan university students had a better conceptual understanding than high school students, both school and university students were having difficulties conceptually understanding Newtonian mechanics. Even, the existing introductory mechanics instructions did not change the dominant misconcpetions held by the students about Newtonian concepts (Bani-Salameh, 2016). The availability of such misconceptions in mechanics topics negatively impacted students‘ achievements irrespective of their achivement levels. Hence, in response to this gap, the present study aimed to address this gap by engaging students in dialogic-practical work in physics laboratories to improve students' mechanics achievement with different ability groups. It is based on the assumption that dialogic-practical work can enable students with mixed ability groups to argue with each other.

The current study was guided by a social constructivist theory of learning (Vygotsky, 1978) and a dialogic theory (Bakhtin, 1986). Vygotsky (1978) argued that knowledge should be actively constructed by placing students' social interaction at the center of the learning and development processes. Here, language serves as both a cultural and a psychological tool through which students' social interactions both with their peers and with other adults are central to creating meaning and promoting academic performances (García-Carrión et al., 2020). On the other hand, Bakhtin (1986) claimed that utterances are inherently dialogic because they contain responses to preceding and anticipated utterances. Students should be engaged in a series of social interactions with their peers and with the teacher to extract the meaning of an utterance. Relying on these theories, scholars developed various strategies to facilitate dialogic teaching truly in science classrooms. For example, Alexander (2018) provides a dialogic teaching framework consisting of five principles to underpin student-teacher interactions. Alexander argued that teachers should recognize the uniqueness of classroom personalities and circumstances and these give them the responsibility for deciding how each dialogic teaching repertoire should be applied.

On the other hand, Mortimer and Scott (2003) characterized dialogic teaching in terms of four types of communicative approaches ranging from interactive to non-interactive and dialogic to authoritative. They argued that the teacher might include episodes of each of the four communicative approaches in a given lesson to facilitate students' learning. Teachers should know when and how to apply these communicative approaches properly. Of course, the dialogic interactive communicative approach has more educational value to develop students' deeper understanding of a topic and provides opportunities to express their ideas, hypothesize, hear the thoughts of their fellow students, argue, and reason out than others (Andersson & Enghag, 2017). In a similar vein, Mercer and Dawes (2014) distinguished disputational, cumulative, and exploratory talk types as having different impacts on students' learning process. Exploratory talk is the most productive and effective form of student interaction that can improve students' science achievement (Andersson & Enghag, 2017). It encourages social interaction and critical thinking to create knowledge and solve problems with each other. Teachers are often advised to promote exploratory talk to enhance student learning.

Therefore, the key features from the argument-driven inquiry model (Walker et al., 2019), communicative approaches (Mortimer & Scott, 2003), and talk types (Mercer & Dawes, 2014) were synthesized to develop a Dialogic Practical Work (DPW) model. Walker et al. (2019) used an argument-driven inquiry model to explore the role of argumentation in constructing scientific knowledge. The argument-driven inquiry model involves nine steps: investigation design, data collection and analysis, argument generation, group arguments, and critique, scientific writing, and peer review. On the other hand, the dialogic-practical work model consisted of four interwoven practical work stages: conceptualization, investigation, conclusion, and scientific explanation as shown in Table 1.

Table 1. Dialogic-Practical work conceptual framework (Source: Belay et al., 2022, p. 235)

Phases of Practical work	Types of Interaction	Types of Talks
Conceptualization		Exploratory
Orientation	*Within Groups Dialogic Interactive Talk*	Disputational
Hypothesis generation		Cumulative
Investigation		
Experimentation	*Within Groups Dialogic Interactive Talk*	Exploratory
Data Interpretation		Cumulative
Conclusion		
Conclusion	*Within Groups Dialogic Interactive Talk*	Exploratory
Reflection		Cumulative
Scientific Explanation		
Summary	*Whole class Authoritative-interactive talk*	Cumulative

The dialogic-practical work model was intended to provide students with opportunities to integrate observables with ideas (Abrahams & Reiss, 2012). Unlike the argument-driven inquiry model, in the dialogic-practical work model, the teacher provided the task and the research questions. The dialogic-practical work model provides the students a freedom to discuss their ideas and views by engaging them in an interactive-dialogic communicative approach during the conceptualization, investigation, and conclusion stages. In contrast, when it comes to scientific explanation, the teacher uses an authoritative-interactive communicative approach to meet curriculum goals. The teacher use this approach to summarize the main points of the topic, review students' preconceptions and misconceptions against the scientific results and theories, and make explicit connections between everyday views and scientific views. The details of the DPW model were presented in our published research article (see Belay et al., 2022).

This study was conducted in an environment where the traditional lecture approach predominated in science classrooms in Ethiopia (Gbre-Eyesus, 2017). Moreover, the majority of secondary school students had no chance to conduct experimental work (Daba et al., 2016; Nigussie et al., 2018). Even, recipe-based practical work is a new addition to physics instructions in secondary schools. As far as the authors' knowledge goes, no study has examined the effect of dialogic-practical work on students' mechanics achievement in Ethiopian secondary schools. Thus, the purpose of this study was to investigate the effect of dialogic-practical work on secondary school students' mechanics achievement.

Method

This study examined how dialogic-practical work affects secondary school students' mechanics achievement in Bahir Dar town, Ethiopia. In this study, a quasi-experimental pre-and post-test design was used. The study selected two governmental secondary schools that had relatively well-equipped and organized physics laboratories using purposively sampling techniques. A purposive sampling technique was used to minimize the effect of variation in laboratory equipment and apparatus in secondary schools. One section from each of the purposively selected secondary schools was selected randomly using a lottery system. The two sections were randomly categorized as dialogic- and recipe-based practical work groups. The dialogic-practical work group had 46 students (20 females, 26 males), whereas, the recipe-based practical group consisted of 45 students (21 females, 24 Males). In this study, 91 secondary school natural science students were participated. In both groups, two classroom teachers and two laboratory assistants having physics background were participated. All the teachers were bachelor degree holders with 15 to over 20 years of teaching experiences in secondary schools.

In this study, the independent variable was the types of practical work strategies (dialogic- and recipe-practical work) implemented in physics laboratories for eight weeks. The dialogic-practical work group was engaged in a dialogic-practical work approach while the recipe-practical work group conducted a recipe-practical work approach. The dependent variable was mechanics achievement. Both groups had little practical work experience. Therefore, both dialogic-practical work and recipe-practical work approaches were new experiences for the participants. Indeed, three sample data were prepared for the two groups before the interventions. These sample data were designed to give hints about how to handle measurement errors, treat anomaly data, control variables, draw graphs, and the need to take the average of the measurements as shown in Table 2.

Table 2. Experiment with a pendulum

Some students experimented to find out the time a pendulum takes to swing a full cycle (period). They made five repeated measurements of one period with a stopwatch. Here are their results.

Measuring one period	Time (seconds)
1st measurement	1.1
2nd measurement	1.2
3rd measurement	0.9
4th measurement	3.5
5th measurement	1.1

Why did they get the exact same time in each measurement?
Here are some possible reasons:

- They did not read the time accurately from the watch.
- They must have been something wrong with the watch or the pendulum.
- Measurements are never exactly the same-there will always be uncertainty.

Explain what you think is the most likely reason:

How should they decide which results they should use?

- Add up all measurements and divide by 5 to get an average
- Task away the 4th measurement, that might be wrong, and then average the rest
- Choose the two measurements that are the same
- Choose the shortest time.

In those secondary schools under this study, there was no prepared physics laboratory manual. Hence, the researchers prepared separate manuals for the dialogic-practical work and recipe-practical work groups. For both interventions, eight activities were selected from mechanics topics. It includes measuring the length, area, and volume of objects; determining the density of objects; Archimedes' principle; determining the coefficients of friction; Newton's 2nd law using Atwood's machine; conservation of linear momentum; period of a simple pendulum; and equilibrium. For the dialogic-practical work approach, the laboratory manual included the specific objectives, the apparatus used, and the guiding questions. All the participating teachers had not previously attended dialogic teaching workshops and had not included dialogic teaching in their physics classrooms.

Hence, five days (25 hours) of training sessions were provided for the teacher and the laboratory assistant who participated in the dialogic practical work. This training was focused on the characteristics of effective dialogic practical work, how to implement it productively, and how to manage students' discussion during laboratory sessions. They were engaged in dialogic practical investigations to get firsthand experiences of implementing it. Students were organized into small working groups of four students. The small groups were mixed-gender and mixed-ability groups. As presented in Table 3, during the pre-laboratory activity session, the teacher introduced the task and provided guiding questions. The goal of this stage was to brainstorm students' current understanding of the topic being investigated. All the groups were encouraged to actively engage in arguing with each other and providing claims based on evidence on the guiding questions. At this stage, students were not allowed to carry out the activities in groups. Students in small groups are asked to craft a tentative scientific argument (formulate a hypothesis) to be investigated during the next stage. When a fundamental disagreement has developed among the students, the teacher purposefully refrained from directly supplying correct answers to students. Instead, students are encouraged to write their hypothesis to be proved in the next stage.

Table 3. Determining the period of a simple pendulum

1. Discuss in groups whether the following statements is/are correct or not?
   - The period of oscillation depends on the amplitude.
   - The rope length is inversely proportional to the vibration period on the pendulum.
   - The vibration period is affected by the pendulum's swinging mass.
   - The heavier a pendulum bob, the shorter its period.
   - The period of a simple pendulum increases as the angle of oscillation increases.

Argue in groups on each of the alternatives by providing evidence.

____
____
____.

Write down one or two hypotheses to be verified during practical investigations.

____
____.

2. By measuring the time for 10 or more periods and then divides by ten, do you think that the decrease in amplitude of the swings will affect the result?

During actual practical work, students determined the data collection trials, the data analysis, the interpretation, and the outcomes of the investigation with minimal guidance from the teacher and the laboratory technician. Every member of the group was encouraged to make a positive contribution to the discussions and decision-making. Students were actively engaged in arguing with each other, providing claims and trying to support them with evidence, setting up the equipment and apparatus, collecting data, and analyzing data. The teacher and laboratory assistant continuously checked how well each group progressed and gave hints and prompts while the students were recording data, analyzing data, and arguing. During the conclusion phase, students are also involved in dialogue and debate within their groups. They assessed whether the finding from the practical work go for or against their hypothesis. One of the group members was asked to reflect on the findings to the whole class, and other groups challenged the presenters by posing questions.

For the recipe-based practical work approach, students were divided into heterogeneous groups of four people in terms of gender and success. In this approach, the manual provided detailed written instructions on specific objectives, the theoretical background of the topic, data collection procedures, data analysis, and interpretation procedures. During the pre-laboratory phase, students were asked to read the theory written in the manual as shown in Table 4. They became well-informed about the outcomes of the practical investigations. During the practical investigation phase, students were instructed to follow a step-by-step procedure to find a pre-determined result. The teacher and the laboratory technician directly instructed the students while setting up the experiment, collecting data, analyzing and interpreting data, and reaching conclusions. Each group prepared a written report following the data obtained. The teacher concluded the outcomes of the practical work for the whole class. Each group's report was examined by the teacher and feedback was given to the students in the next session.

Table 4. Sample theory for the recipe-based practical work approach

A simple pendulum consists of a small mass oscillating to and fro at the end of a very light string. If the amplitude of oscillation is small (less than a bout 10^0), it moves with simple harmonic motion. Period of a simple pendulum is defined as the time taken to make one complete oscillation. The period does not depend on amplitude; there is a continuous interchange of potential and kinetic energy. Therefore, the simple harmonic motion equation is obtained provided θ does not exceed about 10°. Also, the time period is given by, T= $2\pi\sqrt{\frac{L}{g}}$ ….. ($\theta \leq 10°$). Here ℓ is the length of the pendulum (from support to center of the mass) and g is the acceleration of free tall. The period of a simple pendulum depends only on the length of the string and acceleration due to gravity. However, the period of a simple pendulum does not depend on the mass attached to it and the amplitude of oscillation

Students' mechanics achievement scores were collected using 25 multiple choice test items. The items were slightly modified from the Force Concept Inventory (Hestenes et al., 1992), Mechanic Baseline Test (Hestenes & Wells, 1992), Energy and Momentum Conceptual Survey (Singh & Rosengrant, 2003), and Test of Understanding Graphs in Kinematics (Zavala et al., 2017). Few additional items were prepared by the authors on topics that were not covered by the standardized instruments. The items' validity and reliability were assured through discussion with three physics lecturers and piloting with 65 students from non-participating schools. Some modifications were made to the items. The Kuder-Richardson (KR-20) reliability coefficient of the test was found to be 0.74. This test was administered to both groups before (pre-) and after (post) intervention. A paired sample t-test analysis was conducted to make sure there exist differences between pre-and post-test scores within the group. An independent sample t-test was used to analyze the mean score differences between treatment and comparison groups. Likewise, one way ANCOVA was carried out to analyze the difference in mechanics achievement scores among the different achievement levels. To determine if there is a significant difference between the means of the two or three of the achievement levels Bonferroni post hoc test analysis was performed.

Results and Discussion

Results

The descriptive statistics of the students' mechanics achievement scores between the pre-and post-interventions within the group was presented in Table 5.

Table 5. Students paired sample t-test outputs

Groups	N	Pre-MAT score M (SD)	Post-MAT score M (SD)	t	df	Sig. (2-tailed)
Treatment	40	9.28 (2.75)	13.75 (2.31)	-12.82	39	.000
Comparison	38	9.18 (1.86)	9.61 (2.31)	-1.82	37	.08

The treatment group's post-mechanics achievement mean score increased from 9.28 to 13.75 after conducting dialogic-practical work for eight weeks. The paired sample t-test result revealed that there existed statistically significant enhancements between pre-and post-test mechanics scores during the intervention, t (39) = -12.82, p < .001, d= 1.76. The effect size was found to be much larger than the typical value (Cohen, 1988). In addition, Hake's average normalized gain of the treatment group was calculated and found to be 0.42. The average normalized gain had the medium category (Meltzer, 2002). This indicated that the treatment group needs further enhancements between pre-and post-test mechanics scores. Similarly, the comparison group showed improvements in mechanics achievement mean scores from 9.18 to 9.61 between pre-and post-recipe based practical work. However, there was no significant difference between the comparison group's pre- and post-mean scores, t (37) = -1.82, p = .08, d = .21. The average normalized gain was 0.03 (the low category). This revealed that the recipe-based practical work had little effect in enhancing students' mechanics' achievement score.

The treatment and comparison groups' overall pre-and post-mechanics achievement scores were presented in Table 6.

Table 6. The mean achievement scores of the treatment and comparison groups

Groups mean score	Treatment		Comparison				
	N	M(SD)	N	M(SD)	t	df	Sig. (2-tailed)
Pre-MAT score	46	8.89 (2.80)	45	9.05 (2.26)	-0.29	84	.78
Post-MAT score	40	13.75 (2.31)	38	9.66 (2.33)	7.80	76	.000

The result showed no significant differences between pre-mechanics achievement mean score of the comparison group (M= 9.05, SD = 2.26) and that of the treatment group (M = 8.89, SD = 2.80), t (84) = -.29, p = .78. The result revealed that the treatment and the comparison groups had the same levels of understanding about mechanics topics before the intervention. After the dialogic-practical work intervention, the mechanics achievement mean the score of the treatment group (M= 13.75, SD= 2.31) was significantly larger than that of the comparison group (M = 9.66, SD = 2.33), t (76) = 7.80, p < .001, d= 1.76. It showed that the dialogic-practical work approach was more effective in improving students' mechanics achievement as compared to the comparison group.

The dialogic- and recipe-based groups' mechanics achievement scores with different Achievement levels were shown in Table 7.

Table 7. Students' mechanics achievement scores with different achievement levels

Mean scores	Learning groups	N	Mean	SD	df	t	Sig. (2-tailed)
Pre-low	Treatment	18	8.11	2.73	30	-.78	.44
	Comparison	14	8.79	2.49			
Pre-medium	Treatment	15	8.73	2.84	27	-.36	.72
	Comparison	14	9.07	2.16			
Pre-high	Treatment	13	10.08	3.01	23	.61	.55
	Comparison	12	9.42	3.35			
Post-low	Treatment	11	11.64	1.43	22	8.07	.000
	Comparison	13	7.54	1.05			
Post-medium	Treatment	14	13.64	1.74	25	4.34	.000
	Comparison	13	10.69	1.80			
Post-high	Treatment	13	15.61	2.14	23	5.02	.000
	Comparison	12	11.91	1.44			

The result indicated that prior to the intervention, there was no significant difference between low achievement levels of the treatment and comparison groups, t (30) = -.78, p =.44. In a similar vein, no significant difference was observed between the medium achievement levels of the treatment and comparison groups, t (27) = -.36, p =.72. The high achievement levels mechanics mean scores of the treatment and comparison groups also showed no significant differences prior to the intervention, t (23) = .61, p =.55. After the intervention there was a significant difference between low achievement levels, t (22) = 8.07, p < .001, d = 3.27; medium achievement levels, t (25) = 4.34, p < .001, d = 1.67; and high achievement levels, t (23) = 5.02, p < .001, d = 0.93. The effect sizes were very high for all the achievement levels. The result indicated that dialogic-practical work resulted more improvements in mechanics achievement of the different achievement levels (low, medium, and high) as compared to the recipe-based practical work.

Table 8 showed the one way ANCOVA and post-hoc analysis outputs of students' mechanics achievement.

Table 8. The one way ANCOVA and post-hoc analysis outputs for post MAT scores

	Sum of squares	Df	Mean squares	F	Sig. (2-tailed)
Contrast	110.13	2	55.01	16.39	.000
Error	114.22	34	3.56		
Achievement Levels	**Adj.MA Mean scores**	**Achievement level (I)**	**Achievement level (J)**	**MD (I-J)**	**Sig. (2-tailed)**
High	15.03*	High	Medium	1.30	.250
Medium	13.73*		Low	4.17	.000
Low	10.86*	Medium	High	-1.30	.250
			Low	2.87	.001

* The mean values represented the new values adjusted for the covariate

The result showed that a significant difference was observed at least between two achievement levels in their post mechanics achievement scores, F (2,34) = 16.39, p < .001. Students' achievement levels had 49 percent effect in describing the post treatment group's mechanics achievement mean score differences. Bonferroni post hoc test analysis was also performed in order determine if there was a significant difference between the means of the two or three of the achievement levels. The result showed that there was a statistically significant difference in mechanics achievement adjusted means between the high achievement and low achievement levels, p < .001, d = 1.86 and between medium achievement and low achievement levels, p =.001, d = 1.40. However, no significant difference was observed between high achievement level and medium achievement level on the post treatment group mechanics achievement scores, p =.250, d= .67. It indicated that dialogic practical work intervention benefitted high and medium achievement levels more in improving mechanics achievements than the low achievement levels.

Discussion

This study aimed to examine the effects of dialogic-practical work on secondary school students' mechanics' achievement. The finding indicated that the dialogic-practical work significantly improved students' mechanics achievement scores between the pre-and post-interventions. However, the finding showed that the average normalized gain for the dialogic-practical work group was categorized as medium category. This might be due to the short duration of the dialogic-practical work intervention sessions. This study suggested that applying dialogic-practical work for an extended time might enhance students learning gains. The finding of the present study also indicated that those students who conducted dialogic-practical work showed more improvements in mechanics achievement as compared to the recipe-based practical work. This finding was consistent with the works of Ateş and Eryilmaz (2011) who indicated that applying hands-on and minds-on practical work strategies improved students' physics achievement. Unlike Ateş and Eryilmaz, the present study showed explicitly the strategies to engage students in mind-on activities during practical work.

The result also agreed with Radulović et al. (2016) who found that students who conducted inquiry-based experiments and interactive computer-based simulations performed significantly better in physics achievement than those taught with a traditional teaching approach. The result also agreed with Demircioglu and Ucar (2015) who found that applying Argument-Driven Inquiry in a physics laboratory enhanced students' geometrical optics achievement. In the Demircioglu and Ucar study, students got more autonomy to identify problem statements and research questions. In the present study students had no prior practical work experiences, hence the teacher provided the task and the research questions.

The present study contradicted Baloyi (2017) who found that explicit reflective guided inquiry laboratory practical activities did not improve students' physics achievements. The reason for these contradicting results might be due to the absence of argumentation during practical work. Likewise, Walker et al. (2012) also revealed contradicting finding that Argument-Driven Inquiry conducted in college chemistry laboratories did not enhance students' chemistry achievement. The reason behind this contradicting finding might be associated with the difficulty of bringing conceptual understanding in short durations compared to achievement scores.

The finding also showed that secondary school students having different achievement levels improved their mechanics achievements after engaging in dialogic-practical work intervention. Dialogic-practical work was effective in improving high, medium, and low achievement level students' mechanics achievement as compared to the recipe-based practical work. In the dialogic practical work, students with diverse abilities got a platform to work interactively with their peer group and benefitted from the teacher's guidance, encouragement, and constructive feedback. Hence, all achievement levels benefited from the use of dialogic-practical work and gain significantly higher mechanics achievement in post-test scores. The pairwise comparison illustrated that students with high achievement levels and medium achievement levels benefitted more from the dialogic-practical work approach in improving mechanics achievements than those with low achievement levels.

Some studies found similar results (e.g., Gambari & Yusuf, 2016; Yaduvanshi & Singh, 2019). Gambari and Yusuf (2016) found that the computer-assisted Jigsaw II cooperative setting benefitted the high, medium, and low achievement levels with a significant difference among the three achievement levels. Yaduvanshi and Singh (2019) found that a structured cooperative learning approach fostered secondary school students' biology achievement of secondary school students irrespective of achievement level differences compared to the conventional lecture method group. However, some studies contradicted the present finding (e.g., e.g., Buchs et al., 2015; Eshetu et al., 2017; Han et al., 2015). Buchs et al. (2015) found that highly structured cooperative learning conditions resulted in the medium achievement levels progressing more than other achievement levels. Contrarily, Eshetu et al. (2017) found that the cooperative learning method benefited the low achievement levels more than the high achievement levels.

Han et al. (2015) also found that Science, Technology, Engineering, and Mathematics project-based learning activities resulted in low-achievement level students showing higher growth rates on mathematics scores than high and middle-performing students. These findings contradicted the present study due to the following reasons. First, the newly implemented dialogic-practical work approach might result in more cognitive loads on low achievement levels than the medium and high achievement levels. Second, the short duration of the intervention sessions might affect the low achievement levels to develop the skills of conducting actual practical work and arguing with each other.

This finding can be considered promising, because, the intervention was conducted in secondary school physics laboratories where students had very little exposure to practical work as well as dialogic teaching. Many researchers and educators have cautioned that integrating dialogic teaching into practical work per se is a rather challenging task. It will be more challenging, particularly, in those contexts where the lecture method was dominantly implemented in physics classrooms. This study has the following contributions. First it provides useful insights for secondary school physics teachers about what dialogic-practical work should entail and how to apply it. Second, given that dialogic teaching centers on establishing meaningful communication and participation in class, this line of research is prominent in identifying feasible pedagogical approaches to maximize Ethiopian students' physics learning. Third, it might fill the literature gap that exists in the Ethiopian secondary school laboratories context. Lastly, it can be used as a beginning for educational researchers who wants to conduct further research in this area.

Conclusion

The study concluded that dialogic-practical work was an effective method than recipe-based practical work in fostering secondary school students' mechanics' achievement. Furthermore, students who had high, medium, and low achievement levels showed more improvements in mechanics achievement after engaging in dialogic-practical work. It is recommended that physics teachers should attempt to incorporate dialogic-practical work strategies in secondary school laboratories to enhance students' mechanics' achievement. Likewise, the government and other stakeholders should organize seminars, workshops, and continuous professional development training to raise physics teachers' awareness of the benefits of dialogic teaching and the best ways to implement the strategy. Science educators, department heads, and school principals should encourage the use of a dialogic practical work approach in physics laboratories by furnishing physics laboratory rooms with appropriate materials and apparatus. Future research is needed with more sample sizes and different contexts to advance the frontiers of knowledge. Further study is also required to investigate students' retention ability after dialogic-practical work intervention was over.

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