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ORIGINAL ARTICLE

The Effect of Dialogic Practical Work on Secondary School Students' Attitudes toward Physics

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ABSTRACT

This study investigated the effect of dialogic practical work on students' attitudes toward physics. The sample of the study was 91 grade 11 secondary school students selected randomly from two schools in Bahir Dar town, Ethiopia. A quasi-experimental pretest-posttest between groups research design was used. The treatment group participated in dialogic practical work while the comparison group conducted traditional practical work. A 30-item physics attitude questionnaire with Cronbach alpha value of 0.84 was used to collect the data before and after intervention. T-test and one-way ANOVA were used to analyze the data. The result of the study showed that there was a statistically significant difference between treatment and comparison group in favor of the treatment group with no gender differential effects. In addition, the finding showed that the most significant attitude change occurred between the high and low achievement groups. However, no significant difference was observed between the high and medium achievement groups. Dialogic practical work can be used to enhance secondary school students' attitudes toward physics.

KEY WORDS: Achievement levels; attitudes towards physics; dialogic practical work; secondary school students; traditional practical work

INTRODUCTION

Acknowledging that science education has an indispensable value to enhance scientific innovations and technological advancements, countries invest huge resources to improve the teaching and learning of science (Royal Society, 2010). Governments recognize that it is difficult to realize economic growth without remaking the education sector to assure the required level of scientific excellence and technological innovations. Countries should have well-trained science and technology manpower for the needs of the economy and society. Furthermore, the dynamic work environment, globalization, digitalization, and technology-driven world demands a new set of holistic education to equip young people with knowledge, attitudes, and skills in Science, Technology, Engineering, and Mathematics disciplines (Tanenbaum, 2016; Teo, 2019).

There is an alarming rise in the need for highly educated people in science subjects (Hillman et al., 2016; Kind et al., 2007; Osborne et al., 2003). Science disciplines should attract a sufficient number of highly talented individuals entering scientific and engineering careers. The need for a highly educated citizen in Science, Technology, Engineering, and Mathematics are critically important for Sub-Saharan African countries to end abject poverty in the region and to boost economic growth (The African Union Commission, 2015). In collaboration with regional and global financial partners, governments of this region are determined to achieve the developmental goals of becoming a lower middle income country in the near future (The African Union Commission, 2015; Gbre-eyesus, 2017). These countries are using education as a vehicle to realize economic development and improve the standards of living, quality of life, and well-being for their citizens. Initiatives such as Sustainable Development Goals set an agenda to ensure inclusive and equitable quality education and to promote lifelong learning opportunities for all (Webb et al., 2017).

Likewise, the Ethiopian government has an ambition to spur economic structural transformation and sustain accelerated growth toward the realization of the national vision to become a low-middle income country by 2025 (Gbre-eyesus, 2017). Ethiopia has given top priority for science education as a key vehicle to ensure rapid, sustainable, and broad-based growth in the country for the past three decades (Teferra et al., 2018). It has invested in a significant budget for science education with a vision of providing young generations with the required competencies and the skills needed for a growing economy. Accordingly, a rapid expansion of secondary and higher education is needed to provide the workforce for the growing industrial and service sectors (Gbre-eyesus, 2017; Joshi and Verspoor, 2012).

In addition, graduates must be well prepared to be a match for the market, make valuable contributions in their fields,

Science Education International
33(2), 232-241
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enhance their self-employability, assure creativity, innovation, and the advancement of knowledge. The Ministry of Education (MoE) launched successive Education Sector Development reforms and General Education Quality Improvement Programs aimed at improving the quality of science education (Hoddinott et al., 2019; MoE, 2015). The implemented reforms brought about numerous achievements such as increasing the number of qualified teachers in primary and secondary education, improving the infrastructure of the schools, and increasing students' enrolment especially at the primary level (Hoddinott et al., 2019; Teferra et al., 2018).

However, the participation rates for secondary education are still far behind the rest of the world (Gbre-eyesus, 2017; Regmi, 2015). The quality and standards of education at all levels remain unacceptably low (Goshu and Woldeamanuel, 2019; Hoddinott et al., 2019). National Learning Assessment reports have shown that secondary school students' (Grade 10 and 12) national examination physics performance is poor and has shown no signs of improvement (MoE, 2010, 2014). In 2013, only 10.5% of grade 12 students were able to score 50% and above in physics. The majority of the secondary school students did not have the expected knowledge, attitudes, and skills (Teferra et al., 2018).

The lack of quality science education is increasingly seen to constrain countries' abilities to pursue effective economic growth and development strategies (Joshi and Verspoor, 2012; Teferra et al., 2018). However, the teaching and learning process in Ethiopian classrooms remain primarily teacher centered (Gbre-eyesus, 2017; Tadesse and Gillies, 2015). Furthermore, students do not get the opportunity to carry out practical work either individually or in groups in most secondary schools (Daba et al., 2016; Daba and Anbesaw, 2016; Nigussie et al., 2018). Most Ethiopian students are likely to complete secondary schools without having done any basic science experiments.

Scholars have argued that instructional methods have a strong positive impact in improving students' attitudes towards science (e.g., Musengimana et al., 2021). For this reason, providing new learning experiences to students in science laboratories may have an indispensable advantage in promoting their attitudes toward science (Babalola et al., 2020; Millar, 2004). Of course, practical work has a long history in science education in most countries. However, traditional practical work approach is still commonly practiced in most schools and universities (Cramman et al., 2019; Riaz et al., 2020). It has little impact in achieving the intended students' learning outcomes in general (Holmes et al., 2017; Vilaythong, 2011) and students' attitudes toward physics in particular (Sawyer et al., 2017; Wilcox and Lewandowski, 2017). In traditional practical work approach, students are rarely given the space to discuss the steps to be followed or to reflect on their methodology and findings (Sani, 2014).

The present study aimed to address this issue by implementing dialogic teaching as pedagogy in physics laboratories. There is no study to date that has investigated the effects of dialogic teaching in secondary school physics laboratories on students' attitudes toward physics in the Ethiopian context. Therefore, the primary objective of this study was to examine how implementing dialogic practical work in secondary school physics laboratories affected grade 11 students' attitudes toward physics in Bahr Dar town, Ethiopia. It attempts to address the following research questions:

1. How do secondary school students' participating in dialogic practical work significantly differ in their attitude towards physics compared to traditional practical work?
2. How do secondary school female and male students' participating in dialogic practical work significantly differ in their attitudes towards physics?
3. How do secondary school students with different achievement levels differ in their attitude towards physics after participating in dialogic practical work?

Attitudes Toward Physics

Attitudes toward science are considered as psychological preconditions for students' interest to study science and pursue scientific careers (Kind et al., 2007; Osborne et al., 2003). Moreover, students' positive attitudes toward science are associated with their commitment and engagement in learning physics, school performance, and deep understanding of science ideas (Kingir and Aydemir, 2012; Kousa et al., 2018; Liou, 2021). Hence, science education researchers have shown a growing interest in studying students' attitudes toward science.

However, there is no consensus among researchers on the meaning of attitude (Kind et al., 2007; Potvin and Hasni, 2014). Some scholars defined attitude based on students' personal judgment about science either positively or negatively with some degree of regularity across repeated exposures (Kind et al., 2007). Students' personal judgment about science includes a range of attributes about science teachers, science classroom, and science content that can be judged as good or bad, pleasant or unpleasant, interesting, or uninteresting.

Recently, researchers agreed that attitudes toward science, in general, is a multi-faceted construct (Hillman et al., 2016; Kaur and Zhao, 2017; Kind et al., 2007; Navarro et al., 2016). However, these authors differ in categorizing the subscales of attitudes toward science or physics. For example, Kind et al. (2007) used learning science, practical work in science, science outside of school, the importance of science, self-concept in science, and future participation as subscales of attitudes toward science. Kaur and Zhao (2017) also described attitudes toward physics in terms of enthusiasm toward physics, physics learning, physics as a process, physics teacher, and physics as a future vocation. Others, for example, Hillman et al. (2016) used four dimensions whereas Navarro et al. (2016) used seven subscales. The availability of various subscales for students' attitudes toward science resulted in theoretical and methodological concerns. This diversity in the definition of the construct among science education researchers

Science Education International
33(2), 232-241
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makes it difficult to systematically summarize the findings among the literature in different contexts.

In this study, *students' attitudes toward physics* are theoretically conceptualized as the feelings and values held by students toward physics in terms of the dimensions: enthusiasm toward physics, physics learning, practical work, physics teacher, and future vocation expressed in the form of like or dislike (Kind et al., 2007; Kaur and Zhao, 2017). We adapted these dimensions of attitudes toward physics due to the following reasons. First, these authors explicitly provided the definition of the construct attitudes toward physics. Second, they exhaustively included the most important students' attitude dimensions associated with a physics teacher, teaching methodology, and curriculum.

Practical Work and Attitudes Toward Physics

Practical work is widely seen as an essential component of science teaching (Abrahams and Millar, 2008; Abrahams and Reiss, 2012; Hodson, 1991). Babalola et al. (2020) mentioned that doing practical work can enhance the learning of scientific knowledge, motivate, and promote positive attitudes to science, the learning of science, and acquiring laboratory skills. Muchai (2016) showed that (traditional) practical work has positive effects on students' attitudes toward physics compared to traditional lecture methods.

However, other scholars concluded that traditional practical work does not develop students' attitudes towards physics (Sawyer et al., 2017; Wilcox and Lewandowski, 2017). The root problem of traditional practical work is "the unthinking use of laboratory work" (Hodson, 1991, p. 176). Students are pushed to strictly follow experimental procedures provided in the manual to collect, analyze, and interpret data. It has been criticized for the absence of opportunity for the students to have autonomy and control over the experiment (Sani, 2014).

Some curriculum reforms have shifted from traditional practical work into more student centered investigations in general and inquiry based practical work in particular (Akuma and Callaghan, 2019; NRC, 2012; Sesen and Tarhan, 2013). The reforms provide opportunities for students to set up experiments, carry out investigations, interpret data, and drawing conclusions. Some authors argued that inquiry-based practical work has a positive effect on students' attitudes toward physics or chemistry (Kurniawan et al., 2021; Sesen and Tarhan, 2013; Walker et al., 2012). For example, Walker et al. (2012) found that Argument-Driven Inquiry (ADI) improved students' attitudes toward chemistry. Yet, other indicated that ADI did not improve attitudes (Demircioğlu and Ucar, 2012; Ural and Gençoğlan, 2019). The potential benefits of inquiry-based practical work on students' attitudes toward physics are still difficult to conclude.

Some scholars investigated that a given practical work approach can bring an attitude difference regarding gender. Some studies found that females are more likely to develop a positive attitude than males (Anwer et al., 2012; Heng and Karpudewan, 2015; Walker et al., 2012). While others concluded that males developed more positive attitudes toward science and or physics than females (Kousa et al., 2018). Yet other studies revealed that females and males did not show any significant differences in their attitudes toward physics (Zeidan and Jayosi, 2015). It indicates that the effect of gender on students' attitudes toward physics still lacks sufficient evidence.

Others have examined the effects of students' academic achievement levels on their attitudes towards physics. For instance, Kingir and Aydemir (2012) found a positive association between students' attitude and their achievements. Yet others, showed that students' attitudes have a positive influence on their academic achievement (Kousa et al., 2018). However, there are a few studies that contradict the above findings (Fulmer et al., 2019; Osborne and Dillon, 2008; Potvin and Hasni, 2014). For example, Fulmer et al. (2019) found that students from the highest performing schools have low attitudes toward science compared to students from the lower performing schools. Potvin and Hasni (2014) and Osborne and Dillon (2008) argued that students selected from high-performing schools did not show positive attitudes toward physics. Therefore, there is gap in literature regarding the effects of students' achievement levels on their attitudes toward physics. This study investigates the possible attitude differences that may exist between females and males as well as among achievement levels as a result of dialogic practical work.

Dialogic Practical Work Conceptual Framework

The purpose of the present study was to examine the effect of applying dialogic teaching in physics practical work on secondary school students' attitudes toward physics. This study was underpinned by a sociocultural perspective of learning (Vygotsky and Cole, 1978) and dialogic theory (Bakhtin, 1986). Learning is seen as a result of social interaction and the use of language (Andersson and Enghag, 2017; Calcagni and Lago, 2018). Bakhtin (1986) argued that utterances are inherently dialogic because they contain responses to preceding and anticipated utterances. Furthermore, students need to engage in an endless dialogue with each other, directly with the teacher, vicariously by listening to others to extract the meaning of an utterance (Bakhtin, 1986). Learning is a process of collaborative and collective knowledge construction in which answers give rise to new questions forming endless strings of utterances (Calcagni and Lago, 2018).

The study of dialogic teaching has expanded greatly in the past three decades, both theoretically and empirically (Calcagni and Lago, 2018). The relatively wide usage of the term dialogic teaching in the research community makes it difficult to get a single and agreed-on definition. Dialogic teaching has been defined as a pedagogic approach that uses the importance of classroom talk to enhance students learning, thinking, and understanding (Alexander, 2006). Alexander argued that effective dialogic teaching should have the following characteristics. First, questions must be structured to provoke

Science Education International
33(2), 232-241
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thoughtful answers. Second, the answer should provoke further questions and are considered as building blocks of dialogue rather than its terminal point. Finally, the classroom interaction between teacher and students and students-students exchanges should be chained into coherent lines of inquiry rather than left stranded and disconnected.

Mortimer and Scott (2003) also characterized dialogic teaching in terms of four types of communicative approaches ranging from interactive to non-interactive and dialogic to authoritative. In any specific lesson or series of teaching sessions, the teacher might include episodes of each of the four communicative approaches and be considered dialogic overall. It gives an opportunity for the teacher to use a balance of shift between dialogic and authoritative communicative approaches (and vice versa) to make science teaching and learning meaningful (Ametller, 2007; Mortimer and Scott, 2003). Mercer and Dawes (2014) further added that no one of the communicative approaches is better than others in educational terms; rather it is the strategic balance that is important. For students to learn effectively, there will be times to sit quietly and listen to an authoritative explanation. Otherwise, to develop a deeper understanding of a topic, students should have opportunities to express their own ideas, hypothesize, hear the thoughts of their fellow students, argue, reason out, and gain feedback from their teacher.

Practical work should present a unique platform for providing an opportunity for the students to make links between the domain of observables and the domain of ideas (Abrahams and Millar, 2008; Millar, 2004). However, teachers often have difficulty helping students to make these links (Abrahams and Reiss, 2012; Millar, 2004). Abrahams and Reiss (2012) advised teachers to adopt innovative approaches and plan activities to enable students to make these links. Hence, the dialogic practical work (DPW) model aims to incorporate the following essential components of effective practical work. First, the teacher assumes flexible power relations and responsibilities with the students to make practical work effective and realistic (Ametller, 2007; Reznitskaya and Gregory, 2013). At the start of the practical investigation, the teacher elicits students' existing thinking about a topic using a dialogic interactive talk. By the end of the phase, the teacher uses an authoritative non-interactive talk approach to conclude the discussion.

Second, students should be clearly engaged in various talk types at different phases of the practical work. Andersson and Enghag (2017) argued that the knowledge about the outcomes of the different talk types is of utmost importance for teachers when designing appropriate laboratory work sessions. In the DPW model, cumulative, exploratory, and disputational talk types identified by Mercer (1995) are implemented. Exploratory talk is the most valuable form of educational conversation to involve students in discussions concerning the meaning of physics concepts and different procedures instead of just talking about what to do. It allows students to challenge, accept and extend each other's statements and strive for consensus at a linguistic level, thus causing them to evaluate old knowledge and make links to new knowledge at a cognitive level.

Third, the teacher needs to provide explicit guidance for the students at each stage of the practical work. The guidance may include providing scaffolding activities, frequent opportunities for formative assessment, as well as powerful guiding questions. In DPW, guiding questions are designed by the teacher to facilitate students' dialogic engagement. The teacher should also give guidance for the students to make a smooth transition from one task to another. The students' discussions should focus on completing the task and creating new knowledge (Andersson and Enghag, 2017).

The DPW framework consists of four interwoven practical work stages: Conceptualization, investigation, conclusion, and scientific explanation phase as shown in Table 1. In the conceptualization stage, the teacher introduces the topic by providing guiding questions to probe students' prior knowledge. Students should be motivated to argue with each other collaboratively within their groups by exchanging ideas. The teacher's role would be to elicit students' existing thinking about the topic and encourage them to argue on the newly learned idea. The teacher is purposefully refraining from directly supplying correct answers to students. Students in small groups are asked to craft a tentative scientific argument (formulate a hypothesis) to be investigated during the next stage.

At the second stage, students should be involved in setting up the apparatus, taking measurements, and forming data tables. Students work collaboratively to analyze and interpret the data by buildings reason-result relations, analyze the trends of the data, and discuss the accuracy or inaccuracy of these results. Students are expected to do most of the thinking. The teacher's role is to encourage student-student group interactions. During the conclusion stage students discuss their findings thoroughly with their peers and defend the critiques forwarded by others. In this stage, students are expected to reflect on the findings with their peers, compare results to the scientific view, create models, reinforce the scientific views, and revise the formulated hypothesis.

Table 1: Dialogic practical work model

Phases of practical work	Types of interaction	Types of Talks
Conceptualization • Orientation • Hypothesis generation	*Within Groups Dialogic Interactive Talk*	Exploratory Disputational Cumulative
Investigation • Experimentation • Data Interpretation	*Within Groups Dialogic Interactive Talk*	Exploratory Cumulative
Conclusion • Conclusion • Reflection	*Within Groups Dialogic Interactive Talk*	Exploratory Cumulative
Scientific Explanation • Summary	*Whole Class Authoritative -Interactive Talk*	Cumulative

Science Education International
33(2), 232-241
https://doi.org/10.33828/sei.v33.i2.11

The group members would be asked to reflect their findings to the class and other groups would ask questions to challenge their findings. At this stage, students would get feedback to realize the strengths and weaknesses of their conclusions before and after the practical work. The final stage is the scientific explanation. At this stage, the teacher takes the whole responsibility to summarize the main points of the topic. The teacher would also review students' pre- and misconceptions against the scientific results and theories to make explicit the connections between views (e.g., everyday views and the science view) and possible lacks in previous thinking authoritatively. Students evaluate their scientific views through comparisons to the expertise of various sources.

METHODS

The study was based on a quasi-experimental (pre- and post-test) between-groups design implemented on a sample of grade 11 secondary school students, in Bahir Dar town, Ethiopia. There are five governmental secondary schools in the town. To select the participants, first, a convenient sampling technique was used to choose those secondary schools having relatively well equipped and organized physics laboratories. Using a random sampling technique one treatment and one comparison groups from two different schools were selected to avoid contamination due to communication between students outside of the class. The treatment group comprised 46 students (26 males and 20 females) and the comparison group had 45 students (24 males and 21 females). In both groups, students were organized into small working groups of four students. The small groups were mixed gender and mixed ability groups. The treatment group conducted a dialogic practical work whereas the comparison group carried out traditional practical work.

One of the researchers secured ethical clearance from the Department of Science and Mathematics Education, Addis Ababa University. The permission was secured from the district leaders, secondary school principals, and participating teachers' departments. The researcher contacted the participants to inform them the purpose of the study, procedures, possible advantages and disadvantages of being involved in the study. This discussion helped the participants to develop trust and to promote integrity in the research. The researcher prepared an informed consent form that openly expressed the purpose of the study, the benefits of participating in the study, guarantee of confidentiality to the participants, and their right to opt out of the study at any time. While collecting the informed consent form, the researcher did not impose the participants to sign. Only voluntary participants who gave their consent (in writing/aurally) were involved in the study.

In this study, the independent variable was the types of practical work strategies (traditional and dialogic) implemented in physics laboratories. The researchers prepared separate manuals for the treatment and comparison groups. For both groups, eight practical work activities were selected from mechanics topics, including measuring 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. Except for the pedagogical approach, maximum efforts were made to make the apparatus and the laboratory manuals parallel as much as possible to minimize threats of validity.

Participating physics teachers from the treatment and comparison secondary schools mentioned that their students lacked practical work experience. Hence, before the commencement of these eight practical sessions, both the treatment and comparison groups of students were given three sample activities. These activities were aimed to give hints about how to handle measurement errors, treat anomaly data, take average (or mean) of the measurements, control variables, and draw graphs. The traditional practical work manual provided detailed written instructions of specific objectives, theoretical background of the topic, data collection procedures, data analysis, and interpretation procedures to find a pre-determined result. In the treatment group, the manual included only specific objectives and the apparatus used.

The classroom teacher and laboratory assistant who participated in dialogic practical work approach were coming from a strict transmissionist background. Hence, before the intervention was commenced, they were provided professional development training for five days (totally 25 h). This intensive professional development training was given on the characteristics of an effective dialogic practical work, how to implement it productively, and how to manage students' discussion during laboratory sessions. They were engaged in practical investigations to get firsthand experiences of implementing dialogic practical work effectively. One of the researchers was physically present over 12 weeks from the conception to the end of data collection by making observations and giving support to the teachers to make sure that the implementation went as planned.

During the practical investigation, students in the treatment groups were actively engaged in arguing with each other, providing claims based on evidence, in setting the equipment and apparatus, data collection and data analysis. Every student was encouraged to make a positive contribution to the group's discussions and decision making. To keep the implementing teachers in track, occasionally out of the laboratory sessions they were made to critically reflect with the researcher on their class management and guidance they give to their students. The teacher checked how well each group progresses during the activity and gave hints and prompts while the students were recording data, analyzing data, and arguing. Follow-up and support were also provided for the teachers of the comparison group to ensure that they implemented as planned.

Science Education International
33(2), 232-241
https://doi.org/10.33828/sei.v33.i2.11

Students' attitude data were collected with the Amharic version of attitude questionnaire adapted from Kind et al. (2007) and Kaur and Zhao (2017). The questionnaire consists of 30-items using a 5-point Likert scale (ranging from 1-strongly disagree to 5-strongly agree). The instrument validity and reliabilities were assured through experts' validation-discussion and piloting with 65 students from a non-participating school. The pilot data were analyzed using the Statistical Package for the Social Sciences computer software version 21. The calculated Cronbach alpha reliability coefficient of the 30-items was 0.84. This questionnaire was administered to both the treatment and comparison groups before and after the intervention. An independent sample t-test was performed to analyze the mean score differences between practical work groups (the treatment and comparison) and gender (females and males). In addition, one-way ANOVA was performed to determine the mean post attitude differences among achievement levels (low, medium, and high).

RESULTS

Preliminary analyses were performed to ensure that there was no violation of the assumptions of normality and homogeneity of variances of the pre- and post-test data. The normality of the data distribution was checked using skewness and kurtosis and both were found to be within the range of ±1. The homogeneity of the variances was checked. Hence, independent sample t-test and one-way ANOVA was employed to compare groups before and after the intervention. We used an alpha level of.05 for all statistical tests.

The Effect of Dialogic Practical Work on Students' Attitudes Toward Physics

Research question one was aimed to investigate the effect of dialogic practical work on students' attitudes toward physics compared to the traditional practical work approach. First, a paired sample t-test was conducted to compare the pre- and post-interventions mean attitude scores of the treatment and comparison groups as shown in Table 2.

For the treatment group, the result indicated that there was a statistically significant difference between the post mean scores (M=3.90, SD=0.41) and the pre mean scores (M=3.20, SD = 0.28) of the treatment group, t (39) = −9.53, ρ < 0.001, 95% CI [0.55, 0.84], d= 1.99. Its effect size was very large (Cohen, 1988). In addition, the normalized pre-to-post gain for the treatment group was calculated using the formula $(g = \frac{post - pre}{100 - pre})$, where *pre* presents pre-test percent score and *post* represents the post-test percent score on the attitude toward physics. The average normalized gain for the treatment group was $g = 0.39$. The treatment group showed 39% an average attitude gain.

The comparison group also showed a statistically significant difference between the mean post scores (M = 3.44, SD = 0.58) and mean pre scores (M = 3.28, SD = 0.28), t (37) = −2.67, ρ < 0.05, 95% CI [0.05, 0.39], d = 0.41. However, the effect size was small. The comparison group brought about an attitudinal gain of 9%. These results suggest that students participated in dialogic practical work brought more improvements on attitudes toward physics compared to their counterparts between pre and post interventions.

Table 2: The paired sample t-test for pre- and post-attitude mean scores

Groups	Attitude scores	N	Mean	SD	t	df	ρ
Treatment	Pre-mean score	40	3.20	0.28	-9.53	39	0.000
	Post-mean score	40	3.90	0.41			
Comparison	Pre- mean score	38	3.28	0.28	-2.67	37	0.048
	Post mean scores	38	3.44	0.58			

Table 3: The treatment and comparison groups attitude mean scores

Groups	Attitude scores	n	Mean	SD	t	df	ρ
Treatment	Pre-mean scores	46	3.21	0.30	−1.06	84	0.29
Comparison	Pre-mean scores	45	3.28	0.28			
Treatment	Post mean scores	40	3.90	0.41	4.53	76	0.000
Comparison	Post mean scores	38	3.44	0.48			

Table 4: Gender comparison in the pre- and post-mean attitudes scores

Groups	Attitude scores	Gender	N	Mean	SD	t	df	ρ
Treatment	Pre-mean scores	Females	20	3.22	0.33	0.12	44	0.91
		Males	26	3.21	0.28			
Comparison	Pre-mean scores	Females	20	3.24	0.22	-0.73	43	0.58
		Males	25	3.29	0.31			
Treatment	Post-mean scores	Females	17	3.84	0.43	4.53	38	0.47
		Males	23	3.94	0.40			
Comparison	Post-mean scores	Females	16	3.50	0.49	0.62	36	0.54
		Males	22	3.40	0.47			

Second, an independent sample t-test was performed to analyze the treatment and comparison groups' pre and post attitude means scores. As indicated in Table 3, the pre-intervention result showed that the treatment group (M= 3.21, SD=0.30) and the comparison group (M=3.28, SD=0.28) had no significant difference in attitude mean scores, t (84) = -1.06, ρ >.05. The two groups were at the same level in their attitudes toward physics before the intervention.

Next, the two groups' post intervention mean scores were analyzed as presented in Table 3. The result revealed that after the intervention there was a statistically significant difference between treatment (M = 3.90, SD = 0.41) and comparison (M = 3.44, SD = 0.48) groups on attitude toward physics, t (76) = 4.53, ρ < 0.001, 95% CI [0.26, 0.66], d = 1.03. The effect size was much larger than the typical value. The result suggested that students who engaged in dialogic practical work developed more positive attitudes toward physics than the traditional practical work.

Science Education International
33(2), 232-241
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Table 5: The one-way ANOVA comparison of the pre- and post-mean scores of the treatment group's achievement levels

Attitude scores	Achievement levels	N	Mean	SD	ANOVA	SS	df	MS	F	ρ
Pre-mean scores	High	13	3.14	0.29	Between Groups	0.13	2	0.07	0.73	0.49
	Medium	15	3.28	0.24	Within Groups	3.87	43	0.09		
	Low	18	3.20	0.34	Total	4.00	45			
	Total	46	3.21	0.30						
Post mean scores	High	13	4.11	0.33	Between Groups	2.07	2	1.04	0.12	0.001
	Medium	14	4.00	0.32	Within Groups	4.51	37	0.12		
	Low	13	3.58	0.40	Total	6.58	39			
	Total	40	3.90	0.31						

SD: Standard deviation, SS: Sum of squares, MS: Mean of squares

The Effects of Gender on Attitudes Towards Physics

The second research question was about the effect of dialogic practical work on female and male students' attitudes towards physics. An independent sample t-test was performed and the results were tabulated in Table 4. Table 4 indicated that there was no statistically significant difference between female students (M= 3.22, SD= 0.33) and male students (M= 3.21, 0.28) of the treatment group before the intervention, t (44) = 0.12, ρ > .05. Similarly, female students (M = 3.24, SD = 0.22) and male students (M = 3.29, SD = 0.31) of the comparison group did not show a significant difference, t (43) = −0.73, ρ > 0.05. The treatment and comparison groups were at the same level in attitudes toward physics irrespective of gender prior to the intervention.

After the intervention, the treatment group's post mean attitude scores of females (M = 3.84, SD = 0.43) and males (M = 3.94, SD = 0.40) were not statistically significant, t (38) = 4.53, ρ > 0.05, 95% CI [−0.36, 0.17]. Both female and male students of the treatment group showed an increment in the mean scores of attitudes toward physics by 0.62 and 0.73, respectively, after the intervention. For the comparison group, female students (M = 3.50, SD = 0.49) and male students (M = 3.40, SD = 0.47) showed no statistically significant difference in attitudes toward physics, t (36) = 0.62, ρ > 0.54, 95% CI [−0.23, 0.43].

For the comparison group, female and male students improved the mean attitude scores by 0.28 and 0.19, respectively. Gender differences did not have a significant effect on students' attitudes toward physics. Dialogic practical work in particular, improved both female and male students' attitude mean scores regardless of gender. In other words, dialogic practical work resulted more positive attitudes toward physics as compared to the traditional practical work irrespective of gender.

The Effect of Students' Achievement Levels on Attitudes Toward Physics

The third research question focused on examining the effects of students' achievement levels on attitudes toward physics. A one-way ANOVA was performed to analyze the effects of students' achievement levels (high, medium, and low) on students' attitude toward physics. The one way ANOVA analysis results were presented in Table 5. As shown in Table 5, there was no statistically significant difference among high, medium, and low achievement levels in their attitudes towards physics before the intervention, F (2, 43) = 0.73, ρ >.05. It means that, before the intervention, students with high, medium, and low achievement levels showed no attitude mean score differences towards physics.

As indicated in Table 5, there was a statistically significant difference in attitudes towards physics at least between two achievement levels of the treatment group after the intervention, F (2, 37) = 8.51, ρ < 0.01. The Bonferroni *post hoc* test result indicated that statistically significant difference was observed between high achievement level (M = 4.11, SD = 0.33) and low achievement level (M = 3.58, SD = 0.40), ρ < 0.01, 95% CI = [0.18, 0.88], d = 1.45 with typically large effect size. Medium achievement level (M = 4.00, SD = 0.32) and low achievement level (M = 3.58, SD = 0.40) showed a statistically significant difference, ρ < 0.05, 95% CI = [0.08, 0.77], d = 1.16 with typically large effect size.

However, there was no statistically significant difference between high achievement level (M = 4.11, SD = 0.33) and medium achievement level (M = 3.58, SD = 0.32) in post attitudes scores, ρ > 0.05, 95% CI = [−0.24, 0.45], d = 0.34 with a small effect size. Dialogic practical work benefitted high and medium achievement levels more in developing positive attitudes toward physics than the low achievement level.

DISCUSSION

The purpose of the first research question was to examine the effects of dialogic practical work on secondary school students' attitudes toward physics in Ethiopia. The finding of the present study indicated that students who conducted dialogic practical work showed more positive improvements in attitudes toward physics as compared to the traditional practical work. Despite the differences in the types of interventions used, there studies that revealed similar findings with the present study (Kurniawan et al., 2021; Walker et al., 2012). For example, Walker et al. (2012) implemented argument driven inquiry (ADI) approach in General Chemistry I laboratory course to examine student's attitudes towards science. These scholars found that ADI improved students' attitudes toward science, with a significant positive gender effect for female students. In addition, Kurniawan et al. (2021) found that high school

Science Education International
33(2), 232-241
https://doi.org/10.33828/sei.v33.i2.11

students learnt by Inquiry and Jigsaw cooperative learning approaches showed a statistically significant difference in their attitudes toward physics in Indonesia.

Muchai (2016) and Musengimana et al. (2021) also found that practical work has positive effects on students attitudes compared to traditional lecture methods. However, these findings contradicted with the present study. Because the present study found that traditional practical work did not improve students' attitudes toward physics. There are additional studies that contradicted with the present study. These scholars used Argument Driven Inquiry; however, this approach did not improve pre-service teachers and students attitudes toward science (Demircioğlu and Ucar, 2012; Ural and Gençoğlan, 2019). A few survey studies which were conducted in Ethiopia indicated that students had a strong ambition to conduct practical work, despite, the absence of practical work in most secondary schools (Nigussie et al., 2018). Getting the opportunity to do practical work may have an important role in improving secondary school students' attitudes toward physics.

The purpose of the second research question was to compare the effects of dialogic practical work on female and male secondary school students' attitudes toward physics. The result of the current study revealed that dialogic practical work improved both female and male students' attitudes toward physics without statistically significant difference. Some studies reported consistent findings with the present study (Sakariyau et al., 2016; Zeidan and Jayosi, 2015). For instance, Zeidan and Jayosi (2015) found out that the Palestinian secondary school male and female students' did not show significant differences in attitudes toward science. Sakariyau et al. (2016) also showed that there was no significant difference between male and female secondary school students' attitudes toward science in Nigeria.

There are research findings that contradict with the present study (Anwer et al., 2012; Heng and Karpudewan, 2015; Kousa et al., 2018; Walker et al., 2012). Some of these showed that females had more positive attitudes toward science than males (Anwer et al., 2012; Heng and Karpudewan, 2015; Walker et al., 2012). While others revealed that male students had more positive toward attitudes toward science (Kousa et al., 2018). Most studies revealed that there was great disparity between male and female secondary school students' overall physics learning outcomes and attitudes toward physics in particular in the Ethiopian context (Gbre-eyesus, 2017).

The third research question emphasized that dialogic practical work approach brings an attitudes difference among achievement levels. Students from the high achievement and medium achievement levels showed more positive attitude toward physics compared with low achievement level. There is limited literature that explicitly describes the effect of students' achievement levels on attitudes towards physics. There are studies that revealed a positive relationship between students overall achievement and attitudes toward physics (Kingir and Aydemir, 2012). Others argued that attitudes toward physics and or science had a positive effect on students' academic achievement (Cheng and Wan, 2016; Kousa et al., 2018). For example, Kousa et al. (2018) showed that attitudes had a positive influence on students' general academic achievement. However, there are some studies that contradicted with the present study (e.g., Fulmer et al., 2019; Osborne and Dillon, 2008; Potvin and Hasni, 2014). For example, Fulmer et al. (2019) found that the high performing school students' attitudes toward science were low compared to the low performing schools. Potvin and Hasni (2014) and Osborne and Dillon (2008) reported that students selected from high performing schools did not show positive attitudes toward physics.

CONCLUSION

This finding favored the implementation of dialogic practical work over traditional practical work in improving secondary school students' attitudes toward physics. Dialogic practical work improved both female and male students' attitudes toward physics with no significant difference observed between them. The result also revealed that an overall significant difference on students' attitude toward physics was observed among the high, medium, and low achievement levels. Of course, high and medium achievement levels were more favored by the dialogic practical work. However, low achievement levels were not equally benefitted from the dialogic practical work. This study suggested that there is a need to change the traditional practical work into a dialogic practical work to bring more positive improvements on students' attitudes toward physics.

Despite the sample size of the study being low; this study can be a beginning to do further study on this area in the Ethiopian context. These findings can be helpful for policy developers and teachers to reconsider the existing practical work practices in secondary schools. It can also be used to make comparative studies regarding Ethiopian students' physics attitudes. Even though, students with low achievement group showed improvements in their attitudes toward physics; they were not equally benefited from the intervention. Hence, additional quantitative is needed to enhance low achievement level attitudes towards physics by providing appropriate scaffolding mechanism. Furthermore, a qualitative study is required to explore the effect of students' argumentation level on their attitudes toward physics.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ETHICS STATEMENT

This research was conducted by the approval of Addis Ababa University, Science and Mathematics Education Department Ethical Committee. Thus, one of the researchers obtained a written informed consent from Bahir Dar town district leaders and Tana Hiak and Fasilo secondary school principals to conduct this study. Furthermore, the informed consent of all the individual participants included in the study was obtained.

Science Education International
33(2), 232-241
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