

Effects of Blending Virtual and Real Laboratory Experimentation on Pre-Service Physics Teachers' Attitudes Toward Physics Electricity and Magnetism Laboratories

Zemenu Mihret*, Mekbib Alemu, Shimeles Assefa

Department of Science and Mathematics Education, Addis Ababa University, Addis Ababa, Ethiopia

*Corresponding Author: zmihret@gmail.com

ABSTRACT

This study examined the effect of blended laboratory experiments on pre-service physics teachers' (PSPTs') attitudes toward physics laboratories. The research design was a quasi-experimental pre-test and post-test comparing groups. Participants were 63 2nd-year PSPTs' enrolled in a physics diploma program from three colleges of teacher education. The treatment groups performed blended and virtual laboratory experiments, whereas the comparison group conducted real laboratory experiments. Data were collected before and after intervention using a 34-item adapted attitude toward physics laboratory questionnaire with a Cronbach alpha value of 0.765. Data were analyzed using descriptive statistics, paired-sample t-test, one-way ANOVA, and Tukey *post hoc* comparisons. The findings revealed a statistically significant difference in mean post-test results between the treatment and comparison group. The Tukey HSD *post hoc* analysis revealed that the difference in mean between blended and real was statistically significant, but not on other combinations. Descriptive statistics showed slight attitudinal improvement from pre-test to post-test. This improvement was statistically significant for blended and virtual groups but not in real groups. Blending physics laboratory experiments can be used to enhance attitudes toward physics laboratories. Based on the conclusions, recommendations are made.

KEY WORDS: Attitude; blended learning; laboratory; pre-service teachers; physics

INTRODUCTION

There are different factors contributing to low achievement and enrolment in physics at different levels of the education system. One of the factors leading to poor enrolment in physics at different levels of the education system, such as secondary (Opondo, 2009) and the undergraduate and pre-service teacher education (Saputra et al., 2020), is the student's attitude. Despite the vital importance physics as a science subject plays in the contribution of innovations and developments required to attain the vision of a nation, there has been a fall in enrolment and achievement in the subject in many countries (Semela, 2010). Practical work and laboratory experiments result in enhanced student achievement, increased enrolment, and improved attitudes toward physics and physics practical work (Antwi et al., 2021; Ng'ethe, 2016).

The physics subject continues to be considered difficult and unattractive by some students. This can lead to the development of negative attitudes toward the subject. Electricity and magnetism are two of the most important areas in physics but are particularly considered as difficult due to their abstract nature (Mbonyiryivuze et al., 2019). If appropriately implemented, practical work improves students' science experience, problem solving abilities, conceptual understanding, and scientific attitudes (Musasia et al., 2012). Practical work and experiments in physics can be considered

as engaging students in manipulating real or virtual objects, materials, and apparatuses (Millar, 2004).

Despite its importance, physics education is in crisis, and physics enrolment at all levels is low in many African countries. One of the causes of this dilemma is a lack of teacher preparation and insufficient lower-level preparation (Musasia et al., 2012; Semela, 2010). Physics teachers need to help in developing a positive attitude about the subject in their students to prepare them to learn the subject. For this to happen, pre-service physics teachers themselves need to be adequately educated and trained. For instance, in a study that used a quantitative descriptive approach to examine pre-service physics teachers' (PSPTs') attitudes toward physics laboratory, it was found that participants had negative attitudes toward physics laboratory experiments in all aspects of attitude, with the exception of the benefits of physics practical work. These negative attitudes were associated with the design of verification-type practical works that did not lead to an improved understanding of concepts, skills, or interests (Saputra et al., 2020).

Better facilitation needs to be done (Millar, 2004), it is not the practical but rather the design that matters. One of the innovative instructional strategies used in helping students best learn practical work is guided inquiry-based learning. In the literature, there are different levels of inquiry-based

laboratory learning such as confirmatory, structured, guided, and open. However, guided inquiry-based learning was mostly recommended in student type laboratory learning (Rahmi et al., 2018; Ural, 2016). It was also reported that the mode of experimentation used yielded different results on learning outcomes such as attitude toward physics and physics laboratory experiments.

The previous studies have indicated that real equipment and manipulatives were commonly used to enhance students' understandings of science topics in general, but technological advancements have opened up new ways to convey these concepts, such as virtual and blended simulations in physics laboratory experimentation. Scholars have found mixed results on the effects of technology-enhanced learning, such as blended and virtual simulations on physics learning. Some say that virtual simulations benefited equally with real equipment and manipulations (Zacharia and Olympiou, 2011; Zacharia and Constantinou, 2008; Triona and Klahr, 2003). Others have said that real equipment and manipulations benefited student learning more than virtual manipulatives (VMs) (e.g., Marshall and Young, 2006). Still others have argued that virtual simulations benefited student learning more than real/physical manipulatives (PMs) (Zacharia and Anderson, 2003; Finkelstein et al., 2005; Olympiou and Zacharia, 2012). However, there are authors who have reported on the advantage of one over the other. For example, it was reported that virtual simulations have been indicated to provide tangible representations of abstract ideas and concepts as well as physical phenomena (Marshall and Young, 2006), whereas real manipulatives have been found to be beneficial when actual and active touching of materials and apparatus is required (Zacharia and Olympiou, 2011). In recent years, the blended approach has been reported to benefit the affordances of the two modes of experimentations. In much of the research conducted, the procedures followed were not clearly indicated to accept or reject the findings.

An improved alternative, blended physics laboratory experimentation, that combines the affordances of virtual and real manipulatives, has been advocated in recent years (Olympiou and Zacharia 2012; Zacharia and Michael 2016). The results are still inconclusive. It seems that this approach uses the advantages of each manipulative to optimize laboratory experimentation in physics learning. However, it was not free from criticisms. Some authors say that it was not the approach rather the time-on-task, additional instructional resources, and innovative instructional strategies that indicated blended approach was better than each method alone (Means et al., 2009). Other authors reported that blended physics laboratory experimentation benefited student learning than any of the methods but failed to be confident (Brinson, 2015). The authors who reviewed research works on blended physics experimentation come with a conclusion that further research needed to be conducted to get better insight about the issue. For example, Brinson (2015) reviewed more than 115 articles conducted on blended and traditional laboratory education

and concluded that further research needed to be carried out. On the other hand, there is a scarcity of research on the use of blended physics laboratory experimentation on attitude toward physics laboratory on pre-service physics teachers in the Ethiopian context.

Scholars in every scientific field work hard to provide consistent definitions and measurement methods for various constructs, one of which is attitude. The attitude construct has long been examined, and its definition has evolved through time. For example, it has long been regarded as a key concept in social psychology, initially encompassing cognitive, emotional, motivational, and behavioral dimensions. In succeeding decades, the attitude construct was essentially simplified to its evaluative component and its contemporary meaning as likes and dislikes (Schwarz and Bohner, 2001). It is vaguely defined in the literature (Altmann, 2008). The author further added that there were no clear defining characteristics of the concept, despite the fact that attitudes are most commonly defined as a mental state; as a predisposition to a value or belief; and as a value, belief, or feeling. Many definitions are forwarded such as an established opinion and behavior showing this (Abate, 1999), a predisposition to respond in favorable or unfavorable way (Kapucu, 2017), as a combination of beliefs, emotions, and behaviors directed toward a specific object, person, thing, or event (Cherry, 2021).

Student learning attitudes toward a certain subject can again be defined in different ways. In terms of attitude, there are two basic categories to consider: Attitude toward science and scientific attitude. The former are beliefs, feelings, and values held about an object, which could be a scientific activity, school science, the influence of science and technology, or scientists. The latter is a scientific attitude (Aydeniz and Kotowski, 2014; Akcay et al., 2010). The literature revealed that the attitude construct has been defined in science education in a variety of ways and has multiple meanings. Multiplicity of attitude meaning has influenced the development of valid and reliable measures of attitude toward science, as well as the interpretability of attitude research in science education (Aydeniz and Kotowski, 2014). Students' attitude to one or another subject has been proven to lead to good performance in that subject. Negative attitude toward a certain subject makes learning difficult, while positive attitude stimulates students to do effort and leads to the high achievement in that subject (Xavier and Croix, 2016; Veloo et al., 2015).

Many scholars underlined the relationship between attitude and learning. Attitudes have an impact on human behavior and are related to coping with and managing emotions that arise during the learning process (Kaya and Boyuk, 2011). Different scholars have made insights about the relationship between learning attitudes and theories of attitude construction and change. For example, Hsu and Huang (2018) addressed functional and cognitive aspects, with the former emphasizing that individualization and individual idea variation are determinants for attitude modification and the latter claiming

that attitude creation requires more rationality and information. In addition, there are three components of attitude: the cognitive, affective, and behavioral components of the student's work in learning and behavioral patterns (Altmann, 2008; Maria, 2008; Shrigley, 1983).

For a long time, psychologists questioned whether attitudes could predict behavior. Attitudes toward science classes are the best indicators of students' intentions to join science classes (Reid and Skryabina, 2002). Many scholars pointed out the relationship between attitude and behavior and the identified causal mechanisms predict behavior (Fishman et al., 2021; Xavier and Croix, 2016; Guido, 2013). Because of the causal relationship between attitude and behavior, science educators who are interested in changing attitudes can expect a change in behavior (Shrigley, 1983). A variety of scales have been employed to examine the degree to which an individual has a favorable or unfavorable response to an action. The responses are averaged and utilized to assign a single number to each respondent indicating how favorably or negatively the individual views an action. If the end goal is to anticipate behavior, it is essential to measure attitudes toward the given behavior of interest when measuring attitudes qualitatively or quantitatively.

For numerous reasons, attitude toward laboratory was chosen as a learning outcome to investigate the effects of blending virtual and real laboratory designs. First, the present study aimed to investigate PSPTs' responses to various laboratory designs, particularly technology-enhanced laboratories, which are relatively new to the present research context. The second reason was that it has been shown that having a positive attitude toward science/physics education leads to better learning outcomes. The third reason was that practical work and laboratory experiments have been identified as the most effective ways to positively influence students' attitudes on the subject, which, in turn, predicts achievement (Basey et al., 2008). There are also claims that science laboratory education research has not fully addressed student attitudes regarding laboratory class, and that further research is needed in this area (Basey et al., 2008; Hofstein and Lunetta, 2004).

Statement of the Problem

Low physics academic achievement has been a source of worry at many levels of the education system around the world. Scholars have attributed this weak result to a variety of factors, including inadequate learning settings, inexperienced teachers, students' cognitive styles, professional interests, low ability, socioeconomic situation, and so on (Mushinzimana and de la Croix Sinaruguliye, 2016; Olusola and Rotimi, 2012; Erdemir, 2009). However, the majority think that students' attitudes toward physics have a significant part in their physics achievement (Mushinzimana and de la Croix Sinaruguliye, 2016).

An attitude is a psychological condition that determines how a stimulus, in the form of action or behavior, is responded to. That is, the acceptance (positive attitude) or rejection

(negative attitude) of an object is a common tendency of attitudes (Saputra et al., 2020). Attitude is a determining factor in physics achievement, according to studies, and it predicts achievement. For example, scholars found that students' positive attitudes toward science/physics had a positive effect on their academic achievement on high school (Kapucu, 2017; Papanastasiou and Zembylas, 2002) and college students (Saputra et al., 2020). Student attitudes, together with context and knowledge, are one of the factors that determine student competency, according to the 2015 PISA Science Framework (OECD, 2017). Differently, some studies revealed that there was no significant difference in achievement due to attitude. According to a study on freshman physics students conducted by Gungor et al. (2007), students' attitudes toward physics did not significantly predict their physics achievement.

Practical work can increase students' sense of ownership of their learning and can increase their motivation when it is well organized (Antwi et al., 2021; Hofstein and Mamlok-Naaman, 2007). The authors further revealed that practical work offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom when properly conceived, adequately planned and well implemented. Practical courses such as laboratory experimental courses were thought to develop attitude toward science/physics subjects (Luketic and Dolan, 2013; Talisayon et al., 2006). That is, practical work and experiments provide better learning outcomes such as development of scientific knowledge and skills, motivational benefits such as interest and enjoyment, and development of scientific attitudes (Antwi et al., 2021).

As noted, physics is seen as a difficult subject for students to learn because the concepts are abstract and challenging. By eliminating tedious mathematical problems and enhancing practical work and laboratory investigations, these abstract concepts can be linked to real-life situations. However, several constraints, such as a lack of equipment and materials in schools and institutions, make it difficult to use the laboratory successfully and efficiently. In an attempt to tackle these problems, technology enhanced laboratory approaches such as virtual and blended laboratory experimentations can be an alternative. In this context, simulations are a type of technology that are used for an educational purpose which is to translate theoretical scientific knowledge into skills. They are computer programs that simulate the basic elements of the real world to provide controlled learning settings (Aşiksoy and Islek, 2017; Colace et al., 2014). Virtual laboratories, which are a potential alternative to real laboratories, offer numerous educational benefits such as completing time-consuming experiments in less time, performing dangerous experiments in a safe environment, recreating events that would be impossible to observe in a physical laboratory in a virtual environment, serving as a cost-effective alternative to expensive laboratories, allowing students to progress at their own pace, and providing students with immediate feedback to check their learning (Rutten et al., 2012). Thus, innovative

teaching learning strategies and technology supported methods need to be implemented to enhance the level of attitude and achievement in physics education (Guido, 2013).

Although studies are conducted recurrently and various reports are presented, practical work, laboratory experiments, and activities are generally considered to be an integral part of teaching and learning in science subjects in general and physics in particular. In Ethiopia, practical work in general has been recognized as valuable for effectiveness and quality of science education. In primary and secondary levels, practical work is offered in conjunction with science subjects, but in college of teacher educations and universities, laboratory work is given as independent courses and have their own credit hours and instructional materials. Practical work, laboratory experiments, and activities have indispensable contributions to physics learning in many aspects.

The findings of the previous studies suggest that while many researchers have studied attitudes toward physics subject, research on student attitudes regarding physics laboratory experiments is still sparse (Saputra et al., 2020). Examining students' attitudes regarding physics laboratory experiments contributes to the student's investigation of what would happen in physics laboratory experiments and activities. This is because a statistically significant link was reported between student attitude and physics academic achievement (Saputra et al., 2020). On the other hand, a study conducted by Kaya and Boyuk, (2011) regarding attitude toward physics lessons and physics experiments on secondary school students revealed that the average scores of attitudes toward physics lessons and experiments on physics were below the expected level. However, the study of a type of assessment that did not explain in detail what has been done. Another study conducted using experimental approach on student teachers' attitudes toward basic physics laboratory found out that students performed unfavorable attitudes concerning laboratory experiments and activities (Yesilyurt, 2004). Although this study was not clear how the experimental study was carried out, it suggested that students'/pupils' interests should be developed in early ages. Thus, there seems to have inconsistencies in research results regarding attitudes toward physics laboratory experiments and activities. It is important to investigate attitude toward physics laboratories and experiments after intervened with different types of modes of experimentations and facilitated by guided inquiry-based learning. Moreover, the present study was conducted on pre-service physics teachers who are expected to lay foundation regarding quality science education on children and youths.

Technology-enhanced physics learning environments can help students raise their engagement, motivation, and positive attitudes toward science and physics in the digital world (Kapici and Akcay, 2020). Blending a virtual laboratory with a real practical laboratory is one way to use ICT in a learning physics laboratory experiment (Darrah et al., 2014). Research on blended laboratory experiments in science/physics has

yielded mixed results in terms of learning outcomes. For example, a study by (Kapici and Akcay, 2020) on middle school students' attitudes toward science after working with hands-on, virtual, and blended laboratories revealed more positive attitude toward science. Data based on the questionnaire revealed no differences in attitudinal improvement between hands-on, virtual, or combinations of these laboratories, although descriptive data suggested that virtual laboratories are more effective for attitude change than hands-on laboratories. This may be linked to students' overall, but slight, preference for virtual laboratories over hands-on laboratories, as became apparent from the interviews.

In addition, the impacts of combining the use of a virtual laboratory and a research laboratory on university students' knowledge, interest, and attitudes were investigated in a study using conceptual tests in the domain of microscopy and affective questionnaires (Hurtado-Bermúdez and Romero-Abrio, 2020). The findings showed that students might benefit from combining virtual and research laboratories to boost their learning beyond what either experience could provide alone, with the whole being larger than the sum of its parts. Blended experiences, according to the authors, have the potential to be a significant tool for attaining affective and performance-related benefits. Technology-enhanced laboratories have developed as a viable alternative to hands-on laboratories; however, their success in promoting science learning may be influenced by motivation and social factors, as well as how the course incorporates new technologies (Corter et al., 2011). Further research was recommended to continue investigating to enhance promising aspects of blended approach.

Thus, the findings suggest that research on the efficacy of blended mode experimentation in physics is unclear. Students' opinions regarding physics laboratory experiments after experimenting with blended, virtual, and actual manipulatives were the focus of this paper. The purpose of this study, thus, was to examine effectiveness of blended mode of physics experimentation through guided inquiry-based learning on PSPTs' attitude toward laboratory.

The research question designed for this study was:

1. In what way, if any, will learning in experimental physics course using different types of manipulatives result in a significant change in pre-service physics teachers' attitude toward physics laboratory?

METHODOLOGY

This study used a quasi-experimental pre-test and post-test non-equivalent comparison groups design. The study used participants in three intact groups from three college of teacher educations (CTEs) who were enrolled in regular linear physics diploma program. Physics was offered in the program as a separate subject (Linear) as well as integrated (Cluster) with chemistry and biology. The participants of the present study were second year pre-service physics teachers enrolled in a linear physics diploma program in three college

of teacher educations in Amhara region, Ethiopia in the 2020/2021 academic year. The participants in all the three colleges attended the face-to-face Experimental Physics II (Phys 211) course focused on electricity and magnetism concepts. Although the focus of the study was to examine the effects of blending virtual and real laboratory experiments, exclusively virtual and real laboratory groups were also studied for comparison reasons. The study included 63 2nd-year pre-service physics teachers. Participation was entirely voluntary, with informed consent provided by the participants. All of the three groups were taught using guided inquiry-based learning approach. The sites were selected based on prior visit to colleges to examine the availability of resources and human power to undertake the study. In so doing, participants who were taught using real manipulatives were checked for the availability of resources and laboratory materials; those who were taught using blended and VMs were also checked for the availability of resources such as computers and laptops to do simulation experiments. Based on the educational background of physics teacher educators and laboratory technicians, school facilities, and status of colleges, it was observed and assumed that the three colleges were nearly in a similar status.

Experimental Physics II (Phys 201) course was used as an instructional material of the study. This course consisted of electricity and magnetism topics. The real experimental group was taught all the laboratory activities using PMs; the virtual experimental group was taught all the laboratory activities using Physics Education Technology simulations, while the blended experimental group (BEG) was taught using both real and VMs. Teachers and laboratory technicians in all three groups were trained to use guided inquiry based learning to assist the laboratory sessions. The only variation between the three groups was the type of manipulations utilized except for being real, virtual, and blended. The contents in Experimental Physics II (Phys 211) were charging methods, measuring current and voltage, ohm's law, electromotive force and internal resistance, factors affecting the resistance of a conductor, resistors in series and in parallel, determination of the direction of the magnetic field of a straight current carrying wire using compass needle, electromagnets, and electromagnetic induction. Many aspects such as laboratory activities, objectives, pre-laboratory questions, post-laboratory questions, methods of instruction, and assessment and follow-up schemes were similar in all three groups, with the exception of the instructional medium of laboratory experiments.

In the BEG, the intervention was facilitated by guided inquiry method. The blending is made at the activity level. Each activity of the laboratory course was analyzed first and then decision was made on the mode of experimentation used. An important concern is the way to blend PM and VM. To do so, a framework developed by Olympiou and Zacharia (2012) for blending PM and VM use adopted. The framework noted the identification of specific objectives of the experiment, identification of unique affordances of PM and VM consulting the related literature, matching objectives with affordances,

examine the availability of affordances that we had access, and designing training intervention for the participants. To clearly examine the effectiveness of blended mode of experimentation, there was no planned extra time given in either of the study groups nor outside task except post-test laboratory activities in common. In all the three groups, the in-class activities were mostly similar.

Attitude toward laboratory was also the dependent variable of this study. A 5-scale attitude scales toward physics laboratory was adapted and administered for this study to collect affective characteristics of participants. As a result, 34 items were used to assess attitude toward laboratory of participants before and after the intervention. The items in the questionnaire consisted of related constructs, namely, interests, beliefs, confidence, self-efficacy, enjoyment, learning from working with a group, and usefulness of physics for life though these constructs were analyzed in aggregated form. These items were adapted from literature (Yesilyurt, 2004) and others. The items were designed to obtain student teachers' thoughts or views concerning the physics laboratory experiments. Cronbach's alpha was used to determine the reliability of the attitude test questionnaire, obtaining an acceptable value of 0.765.

As it was mentioned earlier, physics laboratory attitude questionnaire consisting of 34 items was administered to PSPTs' formed groups to identify their attitudes before and after intervention. The questionnaire was a 5-point Likert scale and scores were noted down after transforming negative scores into positive scores. Following study of the nature of the data collected and assumption checking, data were analyzed using descriptive statistics and one-way ANOVA. After the implementation of the intervention, compensatory sessions were provided to the PSPTs' in the study. As a result, participant groups that were only working on real manipulatives were allowed to do virtual simulation while those who were only working on virtual experiments were allowed to do real manipulatives.

RESULTS

The different graphical methods such as histograms, normal Q-Q plots, and boxplots of pre-test and post-test scores of students' attitude toward physics laboratory experiments revealed that there was no outlier, and that the data were approximately normally distributed for each independent levels. In addition, for all categories of the independent variable, skewness, kurtosis, and respective Z-scores for pre-test and post-test scores of attitudes toward physics laboratory were examined and found to be within acceptable values, suggesting that the data were approximately normally distributed.

As indicated in Table 1, it can be deduced that mean and standard deviation at pre-test and post-test for BEG were $M = 4.20$, $SD = 0.315$ and $M = 4.46$, $SD = 0.275$, respectively, that yields a mean difference of 0.27 in favor of post-test. In a similar fashion, mean and standard deviation at pre-test and

Table 1: Mean, standard deviations, and difference in means of pre-test and post-test attitude toward physics laboratory

Dependent Variable	Group	N	Pre-test			Post-test		
			M	SD	MD	M	SD	MD
Attitude toward physics laboratory	BEG	16	4.20	0.315	4.46	0.275	0.27	
	VEG	26	4.06	0.256	4.24	0.315	0.18	
	REG	21	4.12	0.309	4.13	0.356	0.01	

BEG: Blended experimental group, VEG: Virtual experimental group, REG: Real experimental group

post-test for virtual experimental group (VEG) were $M = 4.06$, $SD = 0.256$ and $M = 4.24$, $SD = 0.315$, respectively, yields a 0.18 mean difference in favor of post-test. On the other hand, mean and standard deviation at pre-test and post-test for real experimental group (REG), the comparison group, were $M = 4.12$, $SD = 0.309$ and $M = 4.13$, $SD = 0.356$ that yields a mean difference of 0.01 in favor of post-test.

As shown in Table 2, the treatment groups improved significantly, whereas the comparison group exhibited no significant difference, $t(15) = 4.27$, $p = 0.001$, $t(25) = 3.87$, $p = 0.001$, and $t(20) = 0.158$, $p = 0.876$ for BEG, VEG, and REG, respectively. From this scenario, it can be said that blended and virtual physics laboratory manipulatives were effective in enhancing the mean of attitude toward physics laboratory on pre-service physics teachers using physics experimental course. Whereas pre-service physics teachers who were taught with real manipulatives showed no significant change.

The pre-test scores were analyzed using one-way ANOVA analysis to determine academic equivalence of participants before intervention was implemented. Significant difference was not observed between the treatment and comparison groups. In addition, test of homogeneity of variances was conducted for pre-test and post-test scores.

As it is depicted in Table 3, the Levene's test of homogeneity of variances demonstrated that the variances of pre-test and post-test scores of attitude toward physics laboratory were not statistically significantly different, $F(2,60) = 0.292$, $p > 0.05$ and $F(2,60) = 0.827$, $p > 0.442$, respectively. Saying it differently, the variances were equal across the groups implying the homogeneity of variances assumption was met. In sum, tests of normality and homogeneity were met so that parametric tests were chosen for data analysis of the post-test scores.

As indicated in Table 4, there was no statistically significance difference among groups in the mean pretest scores of attitude toward physics laboratory of PSPT, $F(2,60) = 1.02$, $p > 0.05$. The statistically non-significance difference of the pre-test scores among the groups could tell us that pre-service physics teachers were in a similar status regarding their attitude toward physics laboratory before the treatments were employed. That is, before the experiment, the attitudes of the experimental and control groups in physics laboratory attitudes were comparable.

Table 2: Paired-sample t-test for pre-test and post-test scores of attitudes toward physics laboratory

Pair	M	SD	t	Df	Sig. (2-tailed)	Decision
BEG Post-test and Pre-test	0.269	0.252	4.27	15	0.001	Significant
VEG Post-test and Pre-test	0.179	0.236	3.87	25	0.001	Significant
REG Post-test and Pre-test	0.010	0.304	0.158	20	0.876	Insignificant

BEG: Blended experimental group, VEG: Virtual experimental group, REG: Real experimental group

Table 3: Test of homogeneity of variances for pre-test and post-test attitude toward laboratory

Dependent variable	Levene's Statistic	df1	df2	p
Pre-test scores of attitudes toward physics laboratory	0.292	2	60	0.747
Post-test scores of attitudes toward physics laboratory	0.827	2	60	0.442

Table 4: ANOVA analysis of pre-test and post-test attitude toward physics laboratory

Dependent Variable	Sources of variation	SS	df	MS	F	p
Pre-test scores of attitudes toward physics laboratory	Between Groups	0.170	2	0.085	1.02	0.368
	Within Groups	5.03	60	0.084		
	Total	5.20	62			
Post-test scores of attitudes toward physics laboratory	Between Groups	1.04	2	0.520	5.08	0.009
	Within Groups	6.15	60	0.103		
	Total	7.19	62			

On the other hand, there was a statistically significant difference in mean post-test mean scores of PSPTs' on attitude toward physics laboratory, $F(2,60) = 5.08$, $p < 0.05$, respectively. Based on the one-way ANOVA output, a statistically significant difference in mean was observed in between at least two of the study groups of PSPTs'. The partial eta squared, η_p^2 , was calculated and found to be =0.145, indicating a large effect. It can be said that 14.5% of the variation in post-test scores of attitudes toward physics laboratory on pre-service physics teachers was attributed the mode of experimentation implemented. To determine in which of the groups the difference observed, Tukey HSD multiple comparisons test was used.

Table 5 shows the Tukey HSD *post hoc* multiple comparison test of pre-service physics teachers' post-test mean scores of attitudes toward physics laboratory after being taught using different laboratory manipulatives. There was a statistically significant difference in mean scores between those taught using blended mode of experimentation and those taught using real manipulatives, as shown in the Table 5, (MD = 0.336,

Table 5: Tukey *post hoc* analysis of attitude toward physics laboratory post-test scores

Dependent Variable	(I) Mode of Experimentation	(J) Mode of Experimentation	MD (I-J)	SE	p
Attitude toward physics laboratory (post)	BEG	VEG	0.221	0.102	0.084
		REG	0.336*	0.106	0.007
	VEG	BEG	-0.221	0.102	0.084
		REG	0.115	0.094	0.441
	REG	BEG	-0.336*	0.106	0.007
		VEG	-0.115	0.094	0.441

BEG: Blended experimental group, VEG: Virtual experimental group, REG: Real experimental group *.The mean difference is significant at the 0.05 level.

$p = 0.007$). However, there was no statistically significant difference between the blended and virtual laboratory groups, or the virtual and real experimental groups (MD = 0.221, $p = 0.084$ and MD = 0.115, $p = 0.441$, respectively).

DISCUSSION

The effect of blended physics laboratory experimentation on PSPTs' attitudes toward physics laboratories was investigated in the present study. The attitude toward physics laboratory questionnaire was administered twice in the semester, before and after the intervention, in a physics laboratory experiment course offered in teacher education colleges. To that purpose, the findings were discussed and supported by the previous studies. The participants were successfully completed the laboratory course and performed favorable attitudes against laboratory experiments.

In all of the participating groups, there were differences in mean scores from the pre-test to the posttest. The paired-sample t-test revealed that these differences were significant for the blended and virtual experimental groups, but not for the comparison group. Both before and after the intervention, pre-service physics teachers who participated in the treatment and comparison groups had a positive attitude. However, in the treatment groups, the improvement was significant, but not in the comparison group.

According to one-way ANOVA, there was a significant difference in mean between the groups' attitudes about physics laboratory experiments after intervention. The significance differences between the groups implied that the different laboratory learning environments differed. Although there was observed mean difference among all the three groups, *post hoc* analysis revealed that the difference existed between two groups. The findings from *post hoc* analysis showed that PSPTs' who were taught using blended mode of physics experimentation liked physics laboratory experiments more than any other groups. The significant mean difference on the post-test scores regarding attitude toward physics laboratory experiments was observed between blended and real experimental groups. There was no significant difference in mean between the virtual and real experimental groups, as well as the virtual and BEGs.

Actually, the BEG, VEG, and REG post-test mean scores all increased. Pre-service physics teachers in the blended and virtual groups exhibited a significant improvement in their attitude toward physics laboratory between the pre-test and post-test, whereas the real experimental groups did not. BEG had a higher mean score increment in post-test scores than VEG, which was higher than REG. The current study's findings are in line with those of prior investigations. For instance, in the domain of electron microscopy, the findings of combining virtual and research laboratory experiments on university students revealed that the combined activity produces positive affective states in students, such as attitudes and interest in scientific topics (Hurtado-Bermúdez and Romero-Abrio, 2020). Similarly, the effect of practical work on the effectiveness of physics learning was conducted and the results indicated that students' academic performance was enhanced and developed positive attitude toward physics laboratory manipulatives (Antwi et al., 2021).

Although combined activities helped the attitude of PSPTs' toward physics laboratory experiments in the present study other than the exclusively virtual and real ones, the previous studies demonstrated inconsistent results. In a study that investigated blended learning in secondary school science classroom, the finding revealed that no significant change in student attitudes between the blended and comparison group on post-test measure (Hinkhouse, 2013). The author added that neither way of doing laboratory experiments had a major impact on student attitudes toward science. Contrary to this, Alneyadi (2019) found that virtual laboratory environments had a substantial on students' knowledge, achievement, skills, and attitudes concluding that technology-enhanced physics learning environments provided several opportunities.

In a recent study, the effects of three learning environments (hands-on, virtual, and blended) on middle school students' attitudes toward science were compared and the results revealed that there was no significant difference in attitude improvement among the groups (Kapici and Akcay, 2020). Based on descriptive data, the authors claimed that virtual laboratories were more helpful for attitudinal change than hands-on laboratories, which contradicts the findings of the present study. The three groups (blended, virtual, and real) had significantly different attitudinal changes in the present study, and *post hoc* analysis revealed that the BEG improved significantly more than the REG. According to the descriptive statistics, BEG had a greater attitudinal shift in the post-test measure than VEG, which again was followed by REG. To reconcile these disparities, more research in similar contexts is needed; however, in the current study, the PSPTs in BEG and VEG appeared to gain a better alternative to learning abstract concepts when compared to their previous experiences.

Although the combined activities in the present study improved PSPTs' attitudes toward physics laboratory experiments compared to exclusively virtual and real activities, earlier investigations had mixed findings. For example, Brinson

(2015) based on a review of ample related article found that students' themselves are not consistent in their preferences, perceptions, and achievements of educational learning outcomes for different modes of laboratory experiments. This could be due to participants' and teachers' familiarity with instructional strategies, as well as the design and implementation of combined virtual and blended activities (Gumilar et al., 2019).

In addition, one should bear in mind that virtual laboratories have developed as a viable alternative to hands-on laboratories; however, their success in facilitating science learning may be influenced by motivation and social variables, as well as how the course implements new technologies (Corter et al., 2011). In a quantitative study designed to find out PSPTs' attitude toward physics laboratory, negative response was reported in many aspects except indicator of benefits of physics laboratory which had get positive response (Saputra et al., 2020). The authors recommended that physics teacher educators need to improve the design of the physics laboratory to benefit students. It can be deduced that apart from the type of learning environment, the type of instructional strategy matters for the success of laboratory works in physics.

Another study that compared virtual and real experiments found no significant differences in student attitudes toward the usefulness of laboratory in promoting their learning. That is, virtual and physical experiences were viewed by students to have the same effect on their learning provided they were inquiry-based labs, despite an overall preference for using computers in their learning (Pyatt and Sims, 2012). On the other hand, some authors assert the value of physicality, while being challenged by constructivist learning theories (Zacharia, 2007). Apart from that, many authors think that virtual laboratories are a great alternative for a variety of reasons. For example, virtual laboratory experiences may be a viable alternative in rural and high-poverty schools that lack the people and resources to maintain physical laboratories (Watson, 2007). In terms of student performance and attitudes, these studies suggest that virtual laboratories are on par with real laboratories. In today's hands-on learning, what matters most to students may not be the physicality of the equipment (Zacharia, 2007), but rather the opportunity to investigate and alter experimental variables. Because of its strangeness and inconsistent results due to a variety of factors such as measuring instruments, design, context, learning outcomes, and others, more study is needed in a number of different approaches to gain a thorough understanding of the various laboratory delivery methods.

CONCLUSIONS AND RECOMMENDATIONS

According to the results of the attitude toward physics laboratory experiments questionnaire, there was a significant difference among the different laboratory manipulatives. Further investigation indicated that there was a difference between BEG and REG. Although there was a mean difference in post-test scores between virtual and real learning

environments in favor of VEG, it was not significant. The PSPTs' who were taught using blended, virtual, and real laboratory environments had showed different level of improvement on their attitude toward physics laboratory experiments. The paired sample t-test revealed that PSPTs' who were taught using blended and virtual laboratory experiments improved significantly in post-test measures, whereas those who were taught using real laboratory manipulatives did not. All three groups of participants have a favorable view toward laboratory learning environments. After being taught with a blended mode of experimentation instead of virtual and real alone, there was a significant change in PSPTs' attitude toward physics laboratory.

The following suggestions can be made in the hopes of improving students' attitudes about physics labs:

- Different laboratory learning environments must be implemented to assist pre-service physics teachers in developing a favorable attitude toward the physics laboratory and, as a result, the subject.
- In addition to using real manipulatives, a blended mode of experimenting should be devised to foster a positive attitude toward the physics laboratory on pre-service physics teachers.
- Students themselves must do the practices of science such as physics and develop the ability of learning through experiment in CTEs since these teachers are expected to lay foundation in children/youths. In addition, physics teacher educators must participate in different in-service capacity building trainings such as on how to help students learn physics laboratory experiments through different manipulatives. To increase students' attitude toward physics laboratory experiments, lessons should be taught successively.
- Anyone who wants to conduct a blended learning study should provide sufficient training for the participants in terms of instructional materials and strategies. Furthermore, the focus should not just be on the types of manipulatives that will be utilized, but also on how the laboratory learning environment will be facilitated.
- To take advantage of learning with technology, we must be prepared for the future by taking lessons from the time of COVID-19 and other causes for school closure.
- Because the findings on technology enhanced learning in general are mixed, more research should be done in various settings, learning outcomes, and approaches to get the benefits of ICT in our laboratories and throughout the educational system.

ETHICAL STATEMENT

This study was approved by Department of Science and Mathematics Education at Addis Ababa University. To conduct this study, the corresponding author obtained written informed consent from the three CTEs. Furthermore, all study participants provided informed consent.

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