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Effectiveness of blended physics laboratory experimentation on pre-service physics teachers' understanding of the nature of science

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ABSTRACT

The objective of this study was to examine the effectiveness of blended physics laboratory experimentation on pre-service physics teachers' (PSPTs') understanding of the nature of science (NOS) during an electricity and magnetism laboratory course. The study used a non-equivalent comparison group using a pre-test-post-test quasi-experimental design that contrasted blended, virtual, and real mode of physics experimentations. A total of 63 PSPTs, 16 in blended experimental group, 26 in virtual experimental group, and 21 in real experimental group, participated in the study. Except for the type of manipulatives, the experiments in all the three cases were the same. Quantitative Likert-type questions were administered before and after the intervention and open-ended questions were administered after the intervention. The quantitative data were analyzed using one-way ANOVA and ANCOVA, while the qualitative data were categorized under naïve, mixed, and informed views. The results revealed that experimenting with blended, virtual, and real manipulatives were found to be ineffective in enhancing understanding of NOS on the PSPTs'. Apart from the type of experiment used, it was suggested that adequate consideration be paid to NOS issues in the laboratory courses in order to obtain well-educated and trained physics teachers.

Keywords: blended physics laboratory experimentation, guided inquiry-based approach, pre-service physics teachers, understanding of nature of science

INTRODUCTION

Several studies have been conducted over the years to compare the effectiveness of practical work and laboratory experiments with other instructional methods. Practical work and laboratory experiments were shown to have several benefits, including acquiring practical skills, understanding nature of science (NOS) (Akani, 2015; NRC, 2007), understanding science concepts and theories, and developing scientific knowledge (Fadzil & Saat, 2013), promoting positive attitudes, and enhancing motivation for effective science learning (Okam & Zakari, 2017), and then improving achievement (Hinneh, 2017). According to Millar (2004), laboratory experiments are important in helping learners to make links between the domain of objects and observable properties and events, and domain of ideas. However, there are many who oppose laboratory experiments that use failsafe recipe-type procedures to show and verify scientific theories and concepts. These experiments have been criticized for requiring students to complete a series of foolproof experiments with the same expected results for everyone in the class if the guidelines are followed correctly (Bradley, 2005). Yet, being expensive and declining resources threaten to reduce the extent of experimental work in physics courses in the future (Hanif et al., 2009). The case is very serious when we come to developing nations (Godek, 2004) though it is a challenge to developed nations, too (Kaptan & Timurlenk, 2012). The emergence of information communications technology (ICT) brought a variety of modes of experimentation in physics laboratory such as blended and virtual manipulatives as an alternative to the real/physical one. However, research reports regarding effectiveness of these modes of physics experimentations are not consistent and conclusive.

Proponents of real experimentation in science learning provided evidence of the importance of physicality in learning for conscious memory and science/physics learning (Minogue & Jones, 2009; Jones et al., 2006). These group of authors argued that ***physicality*** is important in which manipulation of concrete materials & apparatus (Chan & Black, 2006) and better understanding of multidimensional object/system (Jones et al., 2003) is possible. Similarly, real experiment is better because virtual simulations tend to create virtual worlds (Jensen, 2014; Lindwall & Ivarsson, 2010). Others still claim that not only virtual experimentation, but real experimentation challenges also learning the physical world. With regard to students' learning, one does not have direct experience of the physical world when using either physical tools or technologies. This can be explained by ***human-world versus human-mediating tool-world*** (Bernhard, 2018). Thus, not only virtual simulations but real materials and equipment also provide

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mediated experiences of the natural phenomena. As a result, the authors of this category claim that it is beneficial to use real materials and tools during science education laboratory experiments.

Others contested this notion in that it was the manipulative, either physical or virtual, not the principle of physicality that affects student leaning in physics (Triona & Klahr, 2003; Zacharia & Olympiou, 2011). These authors added that the notion of physicality is against constructivist and cognitive learning theories and claimed that what matters is the manipulation not the mode of experimentation. However, it is important to be aware of the challenges that a student may face while learning about a certain concept or phenomena that was not exposed earlier using virtual simulations.

The second group of scholars argue that virtual experimentation benefited student learning than real experimentation (Chini et al., 2012; Finkelstein et al., 2005; Zacharia, 2007; Zacharia & Olympiou, 2011). Other authors reported that students learned using real and virtual physics experimentations benefited equally (Olympiou & Zacharia, 2010; Triona & Klahr, 2003; Zacharia et al., 2008; Zacharia & Olympiou, 2011). Proponents of virtual experimentation reasoned that it provides more flexible learning environment, illustrating abstract concepts and too large or too small objects/systems, richness, and transparency of contents. This group of academics prefers virtual experiments to real/physical ones. However, virtual experimentation is criticized since it deprives of students hands-on manipulation (Hofstein & Lunetta, 2004), oversimplification (Bernhard, 2018), create virtual worlds (Jensen, 2014; Lindwall & Ivarsson, 2010), and mainly unrelated with student learning. Still others acknowledge the affordances of each modes of experimentation (Gire et al., 2010; Marshall & Young, 2006).

Recently, authors have argued that blended experimentation is the best way to take advantage of real and virtual experimentation using affordances from the two. For example, many studies reported that blending real with virtual physics experimentation benefited students than real or virtual experimentations alone (de Jong et al., 2013; Olympiou & Zacharia, 2012, 2014). However, this group of scholars are criticized for taking middle line without strong arguments. They failed to explain explicitly what supports the combination approach. Many of the studies on blended experimentation were conducted with one learning outcome (mostly conceptual tests) or limited data sources. Additional research should be conducted to develop framework/s (Olympiou & Zacharia, 2012), criticized by the time-on-task (Zacharia & Michael, 2016) focused on the teaching than on the learning (Hinkhouse, 2013). Thus, further empirical research need to be conducted in different contexts, settings, school level, domain, subject, and qualitative design to draw genuine conclusions (Zacharia & de Jong, 2014; Zacharia & Michael, 2016). The authors extended the need for further research concerning blended and virtual experimentations and their relationship with real experimentation given the increasing presence of ICT. Brinson (2015) analyzed over 133 articles related to lab studies and argued that:

> The results of blended lab studies are mixed, and no consensus exists yet regarding best practices, so this is a fascinating and important avenue of further research (p. 13).

The quotation reveals, while ICT growth has benefited the education sector in many ways, there are differences about research findings related learning results and improved use of technology enhanced learning. This then suggests that a series of research will be required to reconcile the issue and improve it in the future.

Many of the research were conducted in developed countries. The socio-cultural, political, economic, and pedagogical perspectives of the Ethiopian students and teachers might be different and need to be considered before large scale implementation. In addition to the continually contending results regarding different modes of experimentation, the same authors reported different findings; many of the research were limited in the learning outcomes investigated, groups compared, curriculum materials used, variables controlled, study design, and others to explore how the participants react and respond to each type of interventions employed; and examine ways for further amendment of the different modes of physics experimentations, if any.

Acquiring scientific literacy, characterized by scientific knowledge and skills, is necessary for successful participation in the present day knowledge-based society. As a result, one of the primary goals of science education is to promote scientific literacy (NRC, 2012; OECD, 2016). NOS is an important component of scientific literacy because it helps students understand science concepts and assists them in making informed decisions. An informed view of the nature of science (VNOS) can be attained through appropriate science laboratory education (Agustian, 2020). One of the science learning goals of laboratory experiences is to gain a better understanding of NOS (Singer et al., 2006). The extent to which students can learn about NOS through laboratory experiments is among the contentious aspects of science laboratory education (Agustian, 2020). Thus, investigating the effects of various modes of laboratory experimentation on understanding NOS is pivotal.

Understanding NOS is taken to be one of the goals of science education in general and laboratory work in particular expected as a learning outcome in many countries (Akani, 2015; NRC, 2007). Teachers' understanding of NOS has already been given significant emphasis in order to enhance students learning outcomes in science education in general and physics education in particular. The physics curriculum and physics teacher educators should work to ensure that pre-service physics teachers (PSPTs) have a clear understanding of NOS. Prior to doing so, physics teacher educators must have clear understanding concerning their PSPTs' conceptions of NOS. Adequately educated and trained PSPTs are critical for promoting the knowledge, skill and attitude of children and youth for their future study. According to available research findings, PSPTs, on the other hand, have not gained such understandings as a result of their subject matter or teacher preparation curriculum. One of the reasons that leads physics PSPTs to have erroneous conceptions about NOS is the use of recipe or verification-type laboratory experiments and activities (Buaraphan, 2011; Prima et al., 2018; Tanel, 2013). When laboratory experiments and activities are appropriately implemented using innovative approaches that engage learners actively in the teaching learning process, they can improve PSPTs' understanding of NOS.

Policymakers and professional organizations have long advocated for students to learn about NOS in addition to its contents (Hind et al., 2001). A science laboratory is a multidimensional enterprise that serves many functions, one of which is to provide students with an understanding of NOS (Agustian, 2020). This purpose, according to the author, is at the heart of science education but is frequently overlooked. This is troubling because understanding of NOS is frequently mentioned as a goal of science education (Abd-El-Khalick & Lederman, 2000; Martin-Dunlop, 2013). This could be achieved if laboratory settings are properly designed and implemented. Because of the development of ICT, the difference in benefits provided by real and virtual experiments encourages researchers to integrate these experiments into the science learning process. Theoretically, blended laboratory experimentation is related to understanding NOS because this learning outcome can be improved through laboratory experiences. Evidence showed that a blended experiment has a high potential for improving student learning outcomes (Brinson, 2015; Gumilar et al., 2019; Zacharia & Michael, 2016). As a result, studying the effects of various modes of physics laboratory is essential for ensuring understanding of NOS which is one goal of science education.

In the Ethiopian context, there are limited resources available regarding teachers and students VNOS. In their study, Daniel and Lemma (2021) looked at the influence of a few demographic characteristics on in-service teachers' VNOS. The findings demonstrated that in-service teachers had naive views on some NOS questions, and that demographic variables had insignificant impact on teachers' VNOS. There was a significant difference in in-service teachers' VNOS based on gender, work experience, and grade level taught, but not across courses they teach. More research into VNOS of in-service teachers from various Ethiopian cultures, according to the authors, is needed to assist improve the quality of science education.

The learning outcomes in physics cannot be achieved just because the students attended physics laboratory experiment classes and sessions. The design and instructional strategy employed is critical for achieving the intended learning outcomes (Siddiqui et al., 2013). These authors reported that guided inquiry-based labs benefited student learning than recipe-based laboratories. Based on the levels of inquiry-based teaching learning approach, guided inquiry primarily allows students producing interpretation of results, while the teacher determines the questions (Imaduddin & Hidayah, 2019). The teacher may control ways to gather data or let students free to use their problem solving methods to answer the questions. In guided inquiry-based laboratory, students are given the opportunity to think independently and help each other with friends and guide students to have individual as well as group responsibilities. These type of laboratory methods help students to think independently and search for an experiment though a given problem and led to enhanced students' learning than cookbook-style laboratories (Afriani, 2019).

Statement of the Problem

Teachers, among other factors, are widely acknowledged as key components of high-quality education. In line with this, PSPTs' education and training are critical, especially for those who will be required to establish the groundwork for children and youth's future studies in engineering, medicine, space science, agriculture, and other related fields. Despite disputes among scholars over the definitions, objectives, implementations, and epistemological significance of laboratory work and experiments in science education, it is largely believed that they are vital and necessary to improve learning results. Laboratory experimentation in physics learning has attracted attention as a result of the rapid rise of ICT and has resulted in a number of modalities of experimentation: real physics experiments, virtual physics experiments, and blended physics experiments. The usefulness of these kinds of physics experiments has been the subject of a lot of research, but the results haven't been consistent and conclusive.

A relatively new approach that many scholars in the area agree is that mixing of real and virtual physics experimentation benefits students physics learning because both were proven to give unique affordances to learners while experimenting (Brinson, 2015; Zacharia & Michael, 2016). The authors, on the other hand, advocate for additional research because the findings call into question long-held norms of teaching and learning practices in science classrooms. Because the research results from effectiveness of the blended experimentation approach are variable and there is no consensus on best practices yet, this is an intriguing and vital area for additional research (Brinson, 2015). Thus, additional studies need to be conducted on wide range of educational levels, topics, samples, contexts, methodologies, data gathering instruments and forms of experimentations. Because ICT-supported instruction is becoming more prevalent in science classrooms, conducting research on effectiveness of the different modes of experimentations and manipulatives becoming increasingly important. This is also very timely in order to examine its effectiveness and identify the area of improvements so as to implement in the time of educational crisis such as COVID-19 pandemic. In the eye of the author, many of the research were conducted in developed countries, thus, the cultural, social, political, economic, and pedagogical perspectives of the Ethiopian students and teachers need to be studied further before large scale implementation. Though there are ample research conducted abroad, limited studies are available on blended physics experimentation taking understanding of NOS as a learning outcome in CTEs. In one hand, understanding of NOS was not well investigated researched in different interventions of science learning and on the other hand, it is believed different among different cultures and communities.

Though there is a general agreement that physics practical works & laboratory experiments and activities improve learning, inconsistency of research results and debates exist on the different learning environments. That is, although blended physics experimentation appeared to be advantageous to virtual and real physics laboratory experimentation, the research findings are still inconclusive and leave room for future research (Brinson, 2015; Hurtado-Bermúdez & Romero-Abrio, 2020; Zacharia & Michael, 2016). Scholars recommended that further study be done using a variety of learning outcomes, large samples, a range of methodologies and instruments, a variety of subjects and topics, different levels of the education system, and so on. For example, scholars suggested further research into the blended mode of physics laboratory experimentation if the study's learning outcomes focused on attributes of NOS (Olympiou & Zacharia, 2012). Understanding of NOS is one of the learning outcome since it is central issue in pre-service teacher education. PSPTs' VNOS have a significant effect on their instructional strategies. The purpose of this study, thus, was examine effectiveness of using blended modes of physics experimentation on PSPTs' understanding of NOS. As a result of the preceding concerns, the following research questions were raised this study:

1. Will learning in experimental physics course using different types of manipulatives result in a significant change in PSPTs understanding of NOS?
2. Which type of experimental physics manipulatives result in better learning of NOS?

RESEARCH METHODOLOGY

This study is part of a larger research into the relative effectiveness of blended, virtual, and real physics laboratory manipulatives for overall physics learning. The study was conducted using a non-equivalent comparison group quasi experimental design with a pre-test-post-test design. It included 63 second-year PSPTs who were enrolled in Experimental Physics II (Phys 211) at three different teacher education colleges (CTEs) located in Amhara Region, Ethiopia. During the second semester of the 2020/2021 academic year, the study was conducted throughout the course schedule (January to March).

The experimental course covers topics such as charging methods, charging, and discharging a capacitor, measuring current and voltage, Ohm's law, series and parallel resistor combinations, factors affecting resistance of a conductor, electromotive force and internal resistance, magnets, and electromagnets, determining the direction of the magnetic field of a straight current carrying wire using a compass needle, and electromagnetic induction. All of these experimental activities were completed over the one-semester intervention period. Intact classes were taken for the study and the colleges were chosen purposively based on a prior visit and survey of the colleges for availability of lab facilities, materials, and equipment because the study was planned to be done on experimental course.

Equivalent physics teacher curriculum was implemented at all three colleges. In addition, for the different types of laboratory learning environments, the same instructional material and guided inquiry-based strategy have been used. That is, aside from the manipulatives utilized in each mode of experimentation, many aspects of lab activities, objectives, pre-lab questions, post-test-lab questions, instructional strategies, and assessment and follow-up procedures were similar in all three groups. After the intervention, those groups that used simulation solely or in a blended fashion received instruction on how to utilize and run the simulations. The role of laboratory experiments in learning physics, inquiry-based lab and its levels, the role of ICT in science education in general and laboratory experiments in particular, how to use physics education technology (PhET) off-line simulations, how to design pre-test-post-test laboratory activities, and common laboratory tasks were among the topics covered in the training for physics teacher educators and lab technicians.

The manipulatives used in each of the three learning environments were different: in the real experimental group (REG), only real/physical materials were used; in the virtual experimental group (VEG), only virtual manipulates/virtual elements on the computer screen were used, along with PhET off-line interactive simulations; and in the blended experimental group (BEG), both real and virtual manipulatives were used. There were no actual materials used in VEG, and no simulations were offered in REG until the post-test. In contrast, a combination of real and virtual manipulatives were used in BEG.

The use of closed and open-ended questionnaires to assess VNOS has been criticized in a variety of ways. In order to address such shortcomings, scholars developed and validated various forms of assessing VNOS (Lederman et al., 2002, 2013). They suggested using both closed-ended and open-ended questionnaires. For this research, the data gathering instruments were a 14-item VNOS questionnaire adapted from Findlay and Souter (2008), and six open-ended questions designed to gather views of PSPTs' on NOS components taken from the literature (Liang, et al., 2008; Miller et al., 2010). Two colleagues, one a PhD candidate from the Department of Science and Mathematics Education and the other an English language lecturer in a CTE, checked the validity of these items after they were translated from English to Amharic. Cronbach's alpha coefficient was used to check the quantitative questionnaires' reliability, and it was found to be.708, which is within the acceptable range.

The quantitative questionnaire was administered both before and after the intervention. After the intervention, all participants were again asked to write about 6 selected NOS elements to support the quantitative data. The replies were classified into three categories: naïve, mixed, and informed views. Assumptions for the quantitative data were tested in order to determine the right type of data analysis techniques. The data was then analyzed using descriptive statistics, one-way ANOVA and ANCOVA.

RESULTS

Pre- and post-test scores of PSPTs' VNOS were approximately normally distrusted, according to graphical methods of test of normality. Similarly, descriptive statistics showed that the skewness, kurtosis, and respective z-scores values of the pre- and post-test VNOS scores were all within acceptable limits. Pre-test VNOS data obeyed the assumption of homogeneity of variances, but post-test VNOS data violated the homogeneity of variances assumption, according to Levene's test of homogeneity of variances. As a result, instead of the one-way ANOVA F-test and the Welch-test was used.

As shown in **Table 1**, PSPTs' VNOS post-test scores, skewness, kurtosis, and z-score values revealed that the data were approximately normally distributed. Besides, the Shapiro-Wilk test revealed no statistically significant deviation from normality, $p>.05$ for all three groups.

Table 1. Test of normality

Group	n	Skewness			Kurtosis			Shapiro-Wilk		
		SS	SE	Z_S	KS	SE	Z_K	Statistic	df	Sig.
BEG	16	.055	.564	.098	-.774	1.09	-.710	.962	16	.703
VEG	26	-.549	.456	-1.20	.630	.887	.710	.949	26	.215
REG	21	-.104	.501	-.208	-.522	.972	-.537	.965	21	.618

Table 2. Mean (M), standard deviations (SDs), and mean difference (MD) of pre-test-post-test VNOS

Dependent variable	Group	n	Pre-test		Post-test		MD
			M	SD	M	SD	
Pre-test VNOS	BEG	16	3.90	.347	3.99	.474	.09
	VEG	26	3.80	.386	3.96	.274	.16
	REG	21	3.93	.426	3.94	.347	.01

Table 3. Pre- and post-test comparison of VNOS using paired-sample t-test

Pair	M	SD	t	df	Sig. (2-tailed)	Decision
BEG post-test-pre-test	.09	.30	1.17	15	.261	Insignificant
VEG post-test-pre-test	.16	.44	1.79	25	.086	Insignificant
REG post-test-pre-test	.02	.46	.15	20	.880	Insignificant

Table 4. One-way ANOVA analysis of pre-test VNOS

Dependent variable		SS	df	MS	F	p
Pre-test VNOS	Between groups	.210	2	.105	6.88	.506
	Within groups	9.15	60	.153		
	Total	9.36	62			

Table 5. Robust tests of equality of means

Dependent variable	Test	Statistic	df1	df2	Sig.
Post-test VNOS	Welch	.050	2	31.99	.951

Pre- and post-test difference in mean scores of VNOS for BEG, VEG, and REG were compared using mean (M), standard deviations (SDs), and mean difference (MD) as shown in table. M, SD, and MD of VNOS pre- and post-test scores are indicated in **Table 2**.

PSPTs who were taught using virtual physics laboratory experimentation had the highest difference in mean VNOS scores, followed by those taught using blended mode of experimentation, MD=.21 for VEG and MD=.09 for BEG. The difference in mean for the comparison group was the least, with MD=.01 for REG. Change was detected after the intervention, despite the fact that the improvement was minimal. The paired-sample t-test was used to compare pre- and post-test VNOS scores with an intervention delivered between the two time points.

Using a paired-sample t-test, **Table 3** reveals whether the difference in mean pre- and post-test VNOS scores after exposing PSPTs' to the different intervention was not significant. That is, neither the experimental nor the comparison group indicated any significant differences as a result of the interventions used. That is, all the three types of physics laboratory learning environments did not bring significant change on PSPTs' understanding of NOS. Let us now use one-way ANOVA to examine the post-test scores of VNOS for the experimental and comparison groups. The pre-test scores were analyzed using ANOVA to see if the participants were in a comparable situation at the start.

As indicated in **Table 4**, the mean pre-test VNOS scores were not statistically significant among the three groups $F(2, 60)=6.88$, $p>.05$. That is, prior to the intervention, PSPTs from three CTEs had similar VNOS. The Welch ANOVA was used because the test of homogeneity of variances for post-test VNOS was significant.

As shown in **Table 5**, mean post-test VNOS scores were not statistically significantly different among PSPTs taught using blended, virtual, and real modes of physics experimentation. That is, the Welch's test results showed that post-test VNOS did not differ substantially across the three groups, $F_W(2, 31.99)=.050$, $p>.05$. There were no statistically significant differences in the mean values of the treatment and comparison groups as a whole. Further analysis was conducted using one-way ANCOVA to examine the effect the intervention on post-test scores taking pre-test VNOS as a covariate.

As detailed in **Table 6**, the ANCOVA analysis result has shown that the different modes of physics experimentations did not result significant mean difference of post-test VNOS on PSPTs, $F(2, 59)=.20$, $p>.05$, with very small effect size $\eta^2=.007$. This F-test value indicated that the mode of experimentation has no significant effect on post-test VNOS. On the other hand, there was a statistically significant pre-test VNOS effect on post-test VNOS, $F(1, 59)=10.21$, $p<.01$, with effect size $\eta^2=.147$. In addition to quantitative data, PSPTs' responses to open-ended questions about the six NOS elements were classified into three levels: naïve, mixed, and informed views. The Kruskal-Wallis test was conducted, and the results are displayed in **Table 6**.

As shown in **Table 7**, the Kruskal-Wallis H test revealed that there was no statistically significant difference in the mean ranks of many aspects of NOS, $\chi^2(2)=1.05$, $p=.592$, $\chi^2(2)=5.55$, $p=.062$, $\chi^2(2)=3.08$, $p=.215$, and $\chi^2(2)=4.24$, $p=.120$ for observations and inferences in scientific knowledge, scientific theories and laws, socio-cultural embeddedness of scientific knowledge, and

Table 6. ANCOVA analysis result of tests of between-subjects effects

Source	Type III SS	df	MS	F	Sig.	η^2
Pre-test VNOS	1.13	1	1.13	10.21	.002	.147
Group	.04	2	.02	.20	.821	.007
Error	6.52	59	.11			
Total	996.08	63				

Table 7. Kruskal-Wallis test on six NOS elements

Aspects of NOS	Group	n	Mean rank	df	X^2	Asymp.Sig
Observations & Inferences	BEG	16	34.78	2	1.05	.592
	VEG	26	29.79			
	REG	20	31.10			
Tentativeness of scientific knowledge	BEG	16	30.66	2	6.26	.044
	VEG	26	37.06			
	REG	20	24.95			
Scientific theories & laws	BEG	16	24.28	2	5.55	.062
	VEG	26	31.90			
	REG	20	36.75			
Social & cultural embeddedness	BEG	16	25.88	2	3.08	.215
	VEG	26	35.02			
	REG	20	31.43			
Creativity & imagination	BEG	16	20.44	2	9.69	.008
	VEG	26	36.35			
	REG	20	34.05			
Scientific methods	BEG	16	26.75	2	4.24	.120
	VEG	26	36.62			
	REG	20	28.65			

scientific methods, respectively. There were, however, a significant difference in mean post-test scores of PRPTs' taught in different laboratory manipulatives for tentativeness of scientific knowledge and creative and imaginative nature of scientific knowledge, $\chi^2(2)=6.26$, $p=.044$ and $\chi^2(2)=9.69$, $p=.008$, respectively. Though the results appear mixed, PSPTs' in VEG tended to have more informed views on the tentativeness of scientific knowledge as well as the creativity and imagination of scientists. In summary, despite slight changes in mean, the treatment and comparison groups had no significant difference in their VNOS.

DISCUSSIONS

The purpose of this study was to examine the effect of a blended mode of physics laboratory experimentation on PSPTs' understanding of NOS using experimental physics course. According to the data analysis results, VEG had relatively the highest difference in mean of pre- and post-test VNOS scores, followed by BEG. REG, which served as the comparison group, had the lowest difference in mean. It may be concluded that there was no substantial change in PSPTs' understanding of NOS as compared to before the intervention. This is not a novel phenomenon and comes as no surprise. Previous research have shown that NOS has not changed despite interventions, including studies involving participants at differing levels.

There was no statistically significant difference among pre-test VNOS scores before the intervention. After the intervention was completed, these items were again administered, and the results revealed that there was no statistically significant difference in mean post-test VNOS scores between treatment and comparison groups. Similarly, after the intervention, PSPTs' conceptions on NOS were assessed, and the results revealed no statistically significant mean difference between the three groups.

Despite the fact that there was no significant mean difference between PSPTs' in the three groups at the beginning, ANCOVA analysis was performed with pre-test VNOS scores as covariates. The results showed that, though there was very little improvement in post-test VNOS scores, it was not significant change. On the one hand, there was no significant difference between the groups; on the other hand, these three types of physics laboratory experimentations did not significantly improve understanding of NOS. This is consistent with previous studies. The current study's findings showed much of what had been reported in the literature about PSPTs' understanding of NOS. For example, learners can be taught about NOS and its aspects through explicit-reflective approach, not simply participating in scientific activities such as observation and experimenting (Abd-El-Khalick & Lederman, 2000; Izci, 2017; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Sardag et al., 2014).

The aspects of NOS, on the other hand, were not an explicit goal of the linear physics curriculum in general, or of the experimental physics II course in particular. This indicates that PSPTs were expected to learn about NOS aspects implicitly when doing process skills like as experimenting, observing, and other related activities. However, there are evidence that taking an explicit course will not ensure adequate understanding of NOS. Daniel and Lemma (2021) have shown that the explicit and implicit instruction teachers got in college, as well as their experience teaching various subjects in school, did not assist them in having the required VNOS and PS. The study showed that science and mathematics in-service teachers had inadequate understanding of NOS. The authors also argued for the necessity of contextualizing college and school content in Ethiopia in terms of NOS and PS.

In the qualitative responses of PSPTs', there was no significance difference among the treatments and comparison groups regarding observations and inferences, scientific theories and laws, social and cultural embeddedness, and scientific methods. Whereas PSPTs who responded naïve, mixed, and informed VNOS differed significantly among the groups regarding tentativeness of scientific knowledge and creativity and imagination of scientists. More specifically, PSPT who were taught using virtual physics experimentation had better informed views on tentativeness of scientific knowledge and creativity and imagination of scientists. These results are in line with previous studies (Findlay & Souter, 2008; Mesci & Schwartz, 2017). For example, Mesci and Schwartz (2017) reported that majority of students significantlly improved their understanding of almost all aspects of NOS whereas several studetns struglled with certain aspects even after a semester science inquiry course. PSPTs may hold a high level of agreement and positive views about all or some aspects of NOS in quantitative but may still hold naïve views when investigated qualitatively (Findlay & Souter, 2008). Motivational, iinstructional, and socio-cultural factors, according to the authors, may influence the existence or absence of changing views on various aspects of NOS. Pre-service science teachers be required to attend additional scientific courses and participate in laboratory experiments and activities in order to improve their understanding of NOS (McComas, 2006). The author further noted that when students participate actively in laboratory experiments and activities, they learn a lot about scientific processes and knowledge construction. This, in turn, has an impact on students' perceptions of NOS aspects. However, studies have found that simply working in a laboratory does not guarantee that NOS knowledge is successfully acquired.

The lesson for us is that understanding of NOS can be made more effective when elements of NOS are added clearly than expressed implicitly in the laboratory activities. The findings of the present study support previous research which indicated explicit and reflective instruction about NOS (Hinkhouse, 2013; Khishfe & Abd-El-Khalick, 2002). In addition, studies supporting both virtual and blended experimentation were measured on learning outcomes related to content knowledge which is the most frequently assessed (Brinson, 2015). There are no or limited studies available if the study's learning outcomes were centered on features of understanding aspects of NOS (Olympiou & Zacharia, 2012).

What this meant is that primarily held VNOS were not changed because of the intervention. The results of this study are generally in agreement with previous studies. Most of the studies the researcher reviewed in examining the alteration of VNOS on pre-service science/physical teachers either implicit or explicit were conducted on theoretical courses based curriculum materials. The present study is on experimental course where three different modes of experimentations were employed to compare their effectiveness by taking understanding of NOS as a learning outcome. A study by Hinkhouse (2013) on investigation of blended learning in high scholl science clasroom reported that student opinions related to NOS remained unchanged. The author and other researchers reported explicit instruction of NOS elements to alter conceptions about NOS (Abd-El-Khalick, 2005; Abd-El-Khalick & Lederman, 2000; Hinkhouse, 2013).

However, there are studies which reported the alteration of NOS views after intervention. For example, pre-service science teachers' VNOS had significantly changed into more contemporary views after a semester science methods course was taught (Shim et al., 2010). NOS aspects were not explicitly shown in the instructional material used in this study rather different skills were assumed to be enhanced implicitly. Others argue that a one-size-fits-all approach to enhancing scientific literacy, in which understanding of NOS is essential, is unacceptable (Glaze, 2018). The author has proposed several alternatives, including shifting from the traditional method of teaching laboratory experiments to an inquiry approach, utilizing technology to actively engage learners, and purposefully incorporating aspects of NOS. Other researchers noted that learning about the history of science/physics improved PSPTs' perceptions of how scientists work to advance scientific knowledge (Tanel, 2013). All of this has demonstrated that there are numerous results and recommendations available on how to improve understanding of NOS.

CONCLUSIONS AND RECOMMENDATIONS

Implementing blended, virtual, and real experimentation using guided inquiry based learning did not alter understanding of NOS on PSPT. The mode of experimentation implemented for a semester on an experimental course on physics consisted of electricity and magnetism contents leave NOS ideas unchanged. This was demonstrated from quantitative as well as qualitative assessment of NOS aspects. Along the way, it was observed that PSPT in the experimental groups were engaged in the lab session, interacting with the teacher, lab technician and with their friends than the comparison groups. The effectiveness of blended mode of experimentation was reported on many learning outcomes in physics but was unable to alter understanding of NOS on PSPTs. It can be implied that implementing different instructional approaches should be in line with the learning outcome that we are aspiring to achieve.

If the different modes of physics laboratory experimentations do not improve VNOS, it is important to consider and integrate NOS elements explicitly in preparing laboratory materials so that PSPTs can help the youth and children they teach. Finally, before selecting and implementing different modes of physics laboratory experiments, it is important to clearly identify the desired changes that will be made by the students. Although the results are not consistent with other studies, it does suggest that there is much to be done about instructing material and strategies design, context, teacher and student related variables and other issues.

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