Use of improvised experiment materials to improve Teacher Training College students' achievements in Physics, Rwanda

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Abstract

The aim of this study was to investigate the extent to which the making and use of improvised experiment materials contribute to students' achievement in Physics. The study used experimental research design and involved students from two Teacher Training Colleges in Rwanda. To conduct this study, a pre-test was given to students. Then, two groups were randomly constituted; the treatment group and the observation group. As intervention, the treatment group was taught using local hands-on materials to supplement the chalk and talk traditional teaching method. At the end of the experimental period, a post-test was conducted to ascertain the contribution of making and use of improvised hands-on materials. Using multivariate analysis of variance, it was found that there was no statistically significant difference between teaching using improvised materials or not. However, reference made to the Bloom's cognitive taxonomy domain, item questions related to analysis have shown a statistically significant difference ($p=.043< .05$) when improvised experiment materials are used in science lesson.

Keywords improvised materials; teacher training college; students' achievement

Introduction

The Government of Rwanda through its Education Sector Strategic Plan (ESSP) 2013/14 - 2017/18 targets to achieve economic development through emphasis on teaching and learning of mathematics and science (Republic of Rwanda, 2013). A study conducted by Nzeyimana (2014) found that instructors' role in Rwanda, is information presenter and evaluator. Moreover, Oguniyi (1977) and Ojo (1981) said that because of lack of science apparatus, practical work becomes difficult to organize. In Rwanda, laboratory activities are not fully performed because of scarcity of laboratory as well as improvising skills (Ndihokubwayo, 2017). This is happening yet scholars advocate for a shift from rote learning to enquiry activities and problem-solving and from teacher-centered approaches to student-centered approaches.

Nowadays, science curricula give emphasis on skills development rather than theoretical knowledge (Angus & Keith, 1992). That being so, the flexibility of Rwandan secondary education curriculum allows improvised experiment materials to fit content and improve science lesson where conventional experiment materials are scarce.

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The ultimate aim behind is to enable children learn by doing and dynamically exploring their environment. In actual fact, science should be taught in such a way that students are exposed to real and practical related activities (Udosen & Ekukinam, 2013). Science experiments help students to increase their self-confidence, creativity, innovation, imagination and curiosity. They also contribute in the development of critical thinking skills.

Studies have indicated that poor performance of students in science in developing countries is not only connected to of teaching/learning methods used but also the ways of science practical are conducted (Ndirangu, Kathuri & Mungai, 2003). For instance, in Rwanda, students do not participate in the choice of the content taught and the teachers dominate the activities in the classrooms, and the source of content is mainly from lecturing (Nzeyimana, 2014). However, with the new shift to Competence Based Curriculum (CBC) in Rwandan education system since 2015 (Republic of Rwanda, 2015), the use of improvised experiment materials will play a key role given that so far science labs are not established and well equipped in all schools. Improvisation is one of the cost-effective ways of learning by doing, where students are given the opportunity to explore and use materials in the surrounding environment. Thus, a creative teacher will always better than the theoretical teacher as he/she demonstrates and relates theory with the real world, students get motivated and develop their science understanding themselves.

Purpose and research hypotheses

This study was set to determine the effect of use of improvised experiment materials to improve Teacher Training College students' achievements in Physics. The following hypothesis guided the study:

Ho: There is no statistically significant contribution of the use of improvised experiment materials on students' achievement in Physics.

Ho: There is no statistically significant difference between the group of students taught using improvised experiment materials and those taught using the chalk and talk method in their achievement in Physics

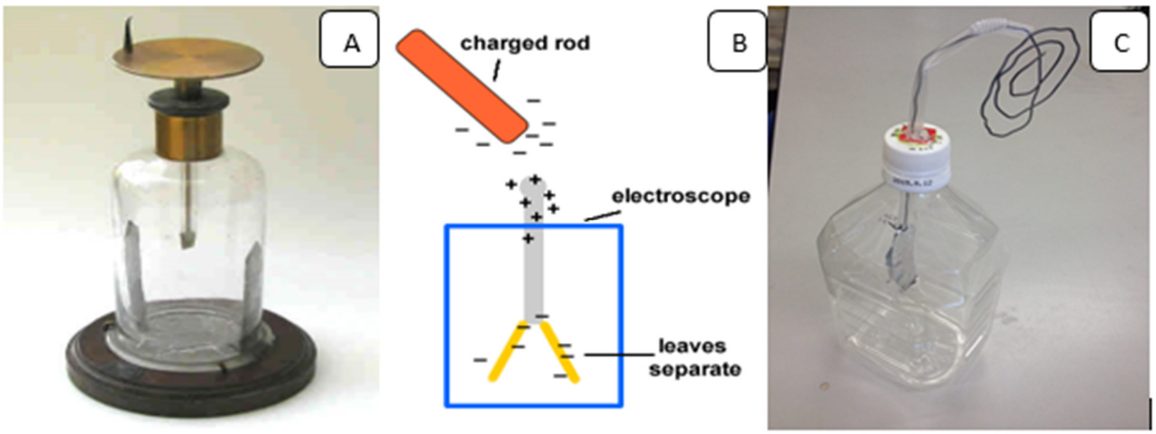
Literature Review

Improvisation in science teaching and learning

Science educators commend the use of improvisation in science lessons (Fatubarin, 2001). According to Adeniran (2006), the improvisation process of instructional materials makes students exposed to creativity, innovation, imagination and curiosity, which are essential to science teaching and learning. Hence, improvisation should not be the prerogative of teachers only. Rather, students should be also being engaged as integral parts of the process (Aina, 2013).

Learning science should start with hands-on experiments that the pupils are familiar with and not with abstract definitions of scientific concepts. Low cost apparatus from locally available materials assume to enrich the capacity to observe, explain and do real science (Sileshi, 2012). Thus, as students apply various facets of their intelligence for the purpose of understanding their natural environment, they are also hold accountable for their observations, inferences, and conclusions (Flick, 1993).

The figure 1 below is an example of conventional science equipment (A) and its improvised counterpart electroscope (C). This simple handmade equipment is made from plastic pet bottle, metal string, aluminum sheets, and plastic straw and can equally illustrate the same phenomenon as industrial made one as the same figure in (B) presents.



Source: A (Quora.com), B (Picquery.com)

Figure 1 Conventional electroscope (A), electroscope working principle (B), improvised electroscope (C)

The hands-on experiment and practical activities in Physics, improve students' learning, help practical skills development, problem-solving, analytical skills, and positive attitudes towards science ((Daniela, Popescu, Ioan, & Andrei, 2015). Johnson et al (1974) in Udosen (2007), for example, studied three categories of science students, namely: (i) a group that learned science from textbooks, (ii) a group that used textbooks and laboratory materials, and (iii) an activity-centered group that dealt primarily with improvised instructional materials and laboratory equipment. They found out that all the groups with textbooks and laboratory materials were relatively behind the group, which was activity-centered, and this group developed the greatest positive attitudes toward learning (Udosen & Ekukinam, 2013). It must be noted that learners achieved more when they are allowed to manipulate apparatus rather than mere listen or observe teachers' idea (Owolabi & Oginni, 2012).

Research design and methodology

Research design

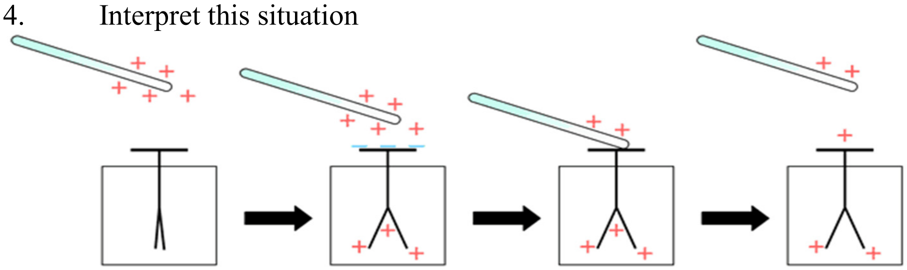
This study adopted an experimental research design whereby a practical research experiment was used (Orodho, Nzabalirwa, Odundo, Waweru & Ndayambaje, 2016). Through experiments, students were given chance to make and use improvised materials from the environment like pet bottles, aluminum foils, balloons, tissues, straws, strings, rubber band and worksheets. Under the guidance of the instructor, students could make experiment materials like cup capacitor, electroscope and many others as indicated on the worksheet. Students recorded and presented results from their respective groups to other groups. Finally, the instructor assisted in drawing conclusions.

Research instruments, sampling techniques and intervention

In this research, researchers used pretest and posttests as instruments for data collection. This enabled to calculate test scores and show the impact of improvised experiment materials in Physics. The Physics Achievement Test results (PAT) were administered to measure the students' achievements. Bloom taxonomy of cognitive domain, in its six level of knowledge and skills, was used in order to see which item question in the test could be improved using science improvisation (Bloom et al. 1956; Anderson and Sosniak, 1994; Anderson and Krathwohl, 2001). That is, with reference to Bloom's taxonomy of cognitive domain, the test for the study was designed with emphasis on open-ended items (see Box 1).

1. A. State two laws of electrostatics

   B. What is static electricity?
2. How can we test different charges? Describe using drawings.
3. Where can we use electrostatics? Give other examples that apply electrostatics.
4. Interpret this situation



5. Charged rubber rods are placed near a neutral conducting sphere, causing a redistribution of charge on the spheres. Which of the diagrams below shows the appropriate distribution of charge on the spheres? List all that apply.

Box 1

The test consisted of 5 open-ended questions on "Electrostatics". The reason behind was that multiple choice test cannot cover the wide range of skills that were targeted. In fact, multiple choice questions can only test narrow content areas and skills especially short-term recall of facts and basic process skills. To evaluate broader abilities of critical thinking, evaluation and problem solving, there was need to focus more on open test that let students explore (Millar, 2004; Ruby, 2001). Theoretically, it was expected that hands-on science would have a significant effect on students' achievements (Cronbach & Snow 1981). This being a purely quantitative study, data were analyzed in the form of numbers and statistics (Kapur, 2015) and presented using tables and graphs (Orodho, Khatete & Mugiraneza, 2016). For these reasons, the test was constructed in guidance of the Bloom's taxonomy cognitive domain of education (Bloom et al. 1956) which divides cognitive learning into six levels: Knowledge (memorization and recall), Comprehension (understanding), Application (using knowledge), Analysis (taking apart information), Synthesis (reorganizing information), and Evaluation (making judgments), from lower-level thinking skills such as memorization to higher order thinking that involves the evaluation of information.

About ninety-five students from two Teacher Training Colleges (TTCs) participated in the study. The first year of TTC, (i.e. senior four) was purposively sampled because it is in that year where topics about electrostatics are taught. Electrostatics unit was chosen because it is the area where experiment materials like electric capacitor, electroscope are much needed. The two TTCs were similar in a way that all did not have science laboratories; hence recourse to improvisation being the only workable choice to practically involve students in Physics lessons. Whereas schools were selected purposively, students in respective groups were selected randomly. Each of the two schools had a control group and an experimental group. To form groups, students were asked to stand up and come in front of the class. They were arranged and told to count from one. Hence, those with odd numbers constituted the control group while those with even numbers belonged to the experimental group. Thereafter, the researchers went ahead and gave a pre-test to students to make sure that both groups have equivalent characteristics. The control group was taught without doing experiments whereas with the experimental group, teaching was enriched with the creation and use of improvised experiment materials. These two groups were taught separately for about eight hours in one month after which a post-test was given to in order to measure the impact of improvised materials on students' achievement.

The experimental group was taught using "improvised materials" created by the students and doing experiments while the control group was taught using drawings. However video watching and group work were used in both groups.

Data Analysis

In this study, "receiving treatment or not" constituted the independent variable while "students' achievement" or the outcome of the test constituted the dependent variable. After administering the test, each of the answers was marked; scores recorded and analyzed using the Statistical Package for Social Sciences (SPSS) (Orodho, Ampofo, Bizimana & Ndayambaje, 2016).

Results

The total number of students sat for both tests is 95 as described by descriptive statistics in Table1.

Table 1 Descriptive Statistics (i.e. mean and standard deviation) of results obtained by the two groups

	GROUPS	*Mean*	*Std. Deviation*	*N*
PRE TEST	*Control group*	*16.67*	*11.865*	*48*
	Experimental group	*15.85*	*12.217*	*47*
	Total	*16.26*	*11.983*	*95*
POST TEST	*Control group*	*37.40*	*15.811*	*48*
	Experimental group	*35.96*	*16.139*	*47*
	Total	*36.68*	*15.905*	*95*

Analyzing tests data using SPSS in its function of general linear model, repeated measures, multivariate analysis of variance between control and experimental groups are illustrated in Table 2.

Table 2 **Results of the multivariate tests for analysis of significance difference**

Effect		Value	F	df	Error df	Sig.	Noncent Parameter	Observed Power[b]
Tests	Pillai's Trace	.655	176.853[a]	1.0	93.0	.000	176.853	1.000
	Wilks' Lambda	.345	176.853[a]	1.0	93.0	.000	176.853	1.000
	Hotelling's Trace	1.902	176.853[a]	1.0	93.0	.000	176.853	1.000
	Roy's Largest Root	1.902	176.853[a]	1.0	93.0	.000	176.853	1.000
Tests * Treatment	Pillai's Trace	.000	.041[a]	1.0	93.0	.840	.041	.055
	Wilks' Lambda	1.000	.041[a]	1.0	93.0	.840	.041	.055
	Hotelling's Trace	.000	.041[a]	1.0	93.0	.840	.041	.055
	Roy's Largest Root	.000	.041[a]	1.0	93.0	.840	.041	.055

a. Exact statistic, b. Computed using alpha = .05, c. Design: Intercept + TREATMENT
Within Subjects Design: TESTS

According to the findings portrayed in Table 2, there is no statistically significant difference between control and experimental groups. Computed at .05 alpha level, the p-value is .84 which is greater than .05 and critical F-value of 3.92 (from 93 degrees of freedom) which is far greater than .041. Therefore, we fail to reject the first Null hypothesis (Ho) because the treatment groups obtained equivalent achievements in both tests (pre- and post-tests).
However, we reject the second null hypothesis because comparing the scores of the group that used improvised experiment materials and the one that used the chalk and talk method, a very strong effect was observed in students' achievement for the groups that used improvised experiment materials, i.e. p-value equals to .000, Figure 2 shows parallelism, whereby the mean score grew from 16.26 to 36.68, between these groups as horizontal axis labels pretest (1) and posttest (2) as well as vertical axis scores along 0 to 50 scores.

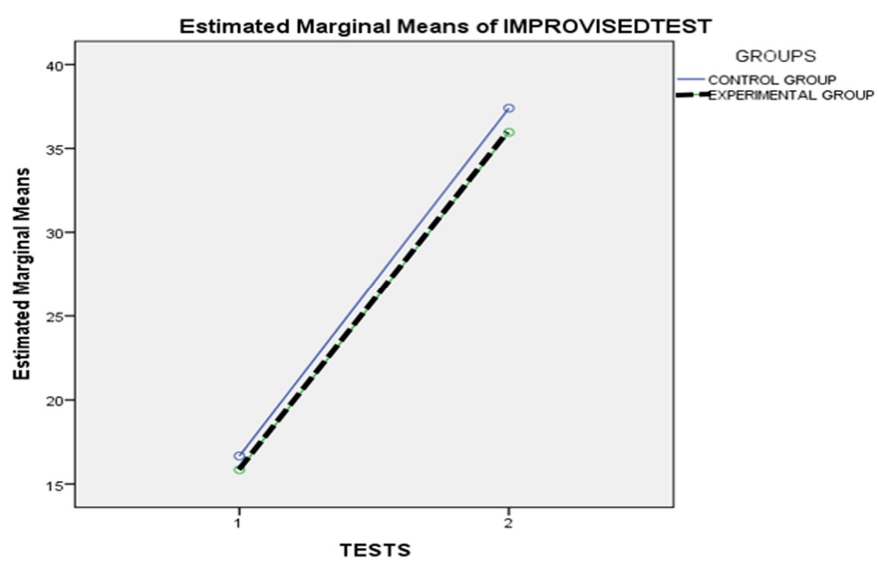


Figure 2 Treatment groups alongside test score

Mean in test items and analysis of each item

Since both groups look similar, a T-test analysis of test items was conducted to see which questions seem to benefit each group. Table 3 presents the figures.

Table 3 Mean of test items

Question no Items	Mark score 50 marks	Mean			
		Control group		Experimental group	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1A	5	3.02	4.06	2.40	2.91
1B	5	0.78	2.39	0.85	1.45
2	10	1.51	2.86	1.35	3.69
3	10	0.78	5.42	0.9	4.03
4	10	0.42	1.2	0.45	1.45
5	10	1.82	2.70	2.30	4.04

Analysis of Items 1A & B (KNOWLEDGE)

In knowledge item, the difference in mean shows a strong statistical significant difference of .003 within 95% difference interval in favor of control group taught theoretically without experiments. The figure 3 shows how the control group performed very well than the experimental group in knowledge item in posttest (from an independent sample test).

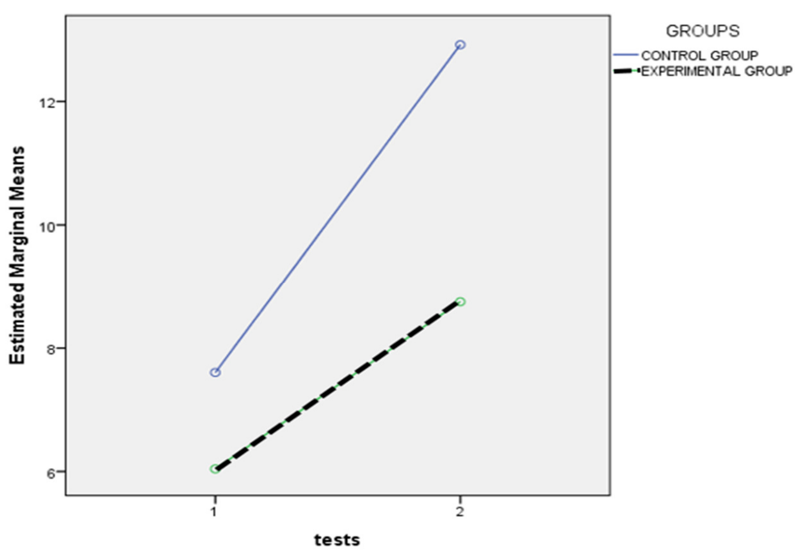


Figure 3 Test score in knowledge item

Analysis of Item 2 (COMPREHENSION)

Independent sample test shows no statistical significance (p=.084) in comprehension item, therefore we do not have enough evidence to reject the null hypothesis (equal mean in treatment groups). However, Figure 4 shows a better performance observed for the experimental group comprehension item questions.

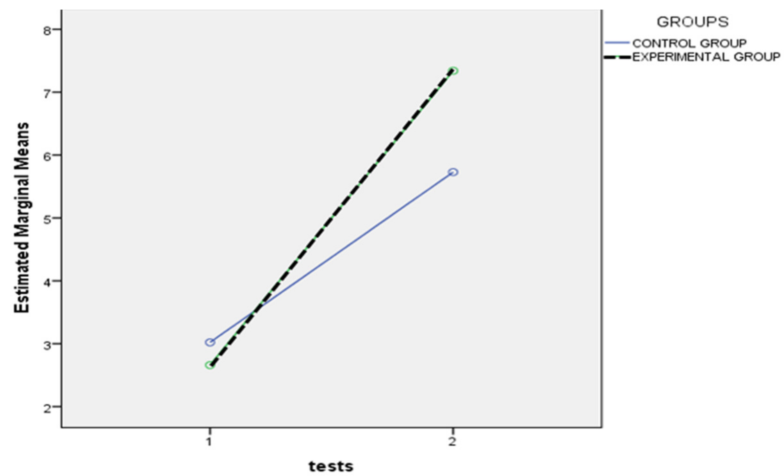


Figure 4 Test score in comprehension item

Analysis of Item 3 (APPLICATION)

Another non-statistical significance difference is observed in application item where .237 instead of .05 (p-value). However, control group seems to perform well as figure 5 displays.

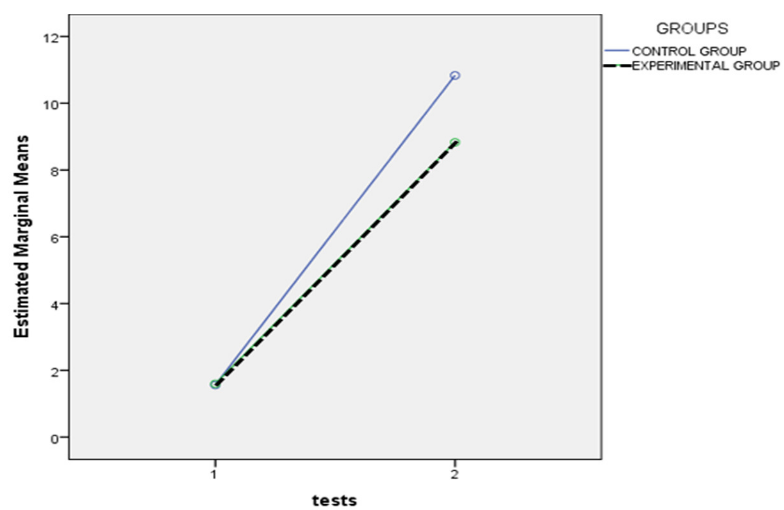


Figure 5 Test score in application item

Analysis of Items 4 & 5 (ANALYSIS)

The analysis items 4 & 5 are statistically significant (.043) since the difference in treatment groups is greater than .05 p-value in 95% difference interval. In order words, this means that we are 95%

sure that improvised experiments can enhance students' analytical skills. For instance, this difference shows that experimental group performs well than the control group in analysis items 4 & 5 according to figure 6. Control group has 7.6 mean alongside its counterpart experimental group having 10.94 means. This shows how these groups are different and the scores are scattered; as also shown by the standard deviation. Hence, the second null hypothesis (H0) saying that groups' means are equal is rejected. Instead, there is a significant difference in control and experimental groups in favor of experimental group taught with hands-on improvised materials.

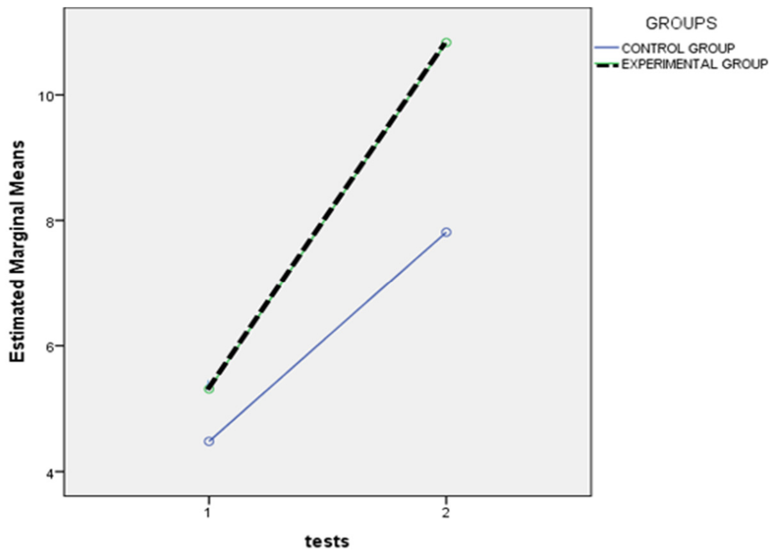


Figure 6 Test score in analysis item

Discussion of Results

In the present study, there was no impact of improvised materials on students' achievement in comparison with students taught without performing experiments. This may be caused by the fact that teaching intervention given to students was constituted by video observation about electrostatics phenomena and experiment like working principle of electroscope (demonstration of charging by friction, induction, and conduction), lightning and thunderstorm among other factors. Same result was found when aiming at inquiry science activity, the result failed to support the effectiveness of hands-on science teaching (Shimizu, 2004). Generally, assessments of the experimental studies did not all yield a positive correspondence between hands-on science and test scores (Suleiman, 2013). Another cause of failing to show the impact of improvised materials may be that both groups were given same time of teaching intervention and this may affect experimental group which needs more time to create and use materials. Time constraints may also contribute to a differential impact of hands-on science based on student ability. If this is true, then when taught using hands-on science they cover less material in class and hence have a short content to revise while preparing for the test (Ruby, 2001).

In the present study analytical items question favor students taught with improvised materials over their counterparts in control group. Actually, the theoretical rationale given for the impact of hands-on science on students' achievement did not stay unquestioned. Critics argue that hands-on science may reduce students' achievement as well as improve it. Whereas proponents argue that hands-on science helps students visualize abstract ideas, opponents argue that it has the ability to confuse as well as clarify (Atkinson 1990; Hodson 1996; Wellington; 1998).

Hands-on science also offers students additional opportunities not to learn as they may be busy doing activities but not thinking about the topic (Ruby, 2001) . This finding concurs with what present study communicated. In fact, the control group performed better than experimental group in knowledge item related question while students experimental group are just excited by experimentation. It is advisable however for teachers not to expect exceptional improvements in experimenting skills after practicing just a few experiments. Instead, students need multiple chances to improve these skills in different contexts (Padilla, 1990; Lati, Supasorn & Promarak, 2012).

Conclusion

The analysis and the discussion of the findings converged to three major points. The first is the fact that there is no statistical significant difference between groups in the sampled schools. The second is the fact that there was a strong significant difference appeared in pretest and posttest when both control and experimental group are taught a new content. The third is related to the fact that there was no significant difference between these groups in both tests when the experimental group gets intervention of improvised experiment. The question now is: Does it mean that the improvised materials have weak effect? The answer would be 'No'! It actually depends. For instance, as observed in this study using Bloom's taxonomy, the knowledge item questions seem to be well performed by control group taught using chalk and talk whereas experimental group shows a better performance in analytical item questions. It was indeed observed that students are motivated and excited in creativity and use of improvised materials. Hence, in view of the shortage of science labs in Rwandan schools and the imperatives related to the implementation of the Competence Based Curriculum, the present study ends by highly recommending Physics teachers to use improvised experiment materials in their daily teaching activities so as to improve the students' learning and achievements.

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