

## Teaching Grade 11, physical sciences using locally available materials (LAMs): A case of water recycling at household level

Makoni Robert Davison & Atagana H.I.

Institute for Science and Technology Education, University of South Africa.

Email: rdmakoni@gmail.com

### **ABSTRACT**

The study seeks to evaluate the effectiveness of teaching physical sciences using locally available materials (LAMs), as a case for a culture of improving teaching in South African Schools. The significance of chemistry research-based teaching (RBTEA) approach integrating LAMs as concept was investigated in grade 11.20 students and their teachers from 4 secondary schools participated in this study. Diagnostic tools for measuring performance in the students' invention scenario of: *Water-recycling at household level device using LAMs* were Research-based Tests (RBT) and Rubric Assessment Tool (RAT).

Relatively high mean scores obtained from one-way ANOVA results for experimental groups A and B respectively: in RAT:  $\bar{X} = 69.2$ ;  $SD = 17.541$  and  $\bar{X} = 68.6$ ;  $SD = 14.893$  point out those students experienced a constructivist environment and they had the opportunity to develop inter-personal skills through RBTEA approach. The reason for poor performance in control groups C and D respectively in RAT:  $\bar{X} = 49.2$ ,  $SD = 19.110$  and  $\bar{X} = 35.6$ ;  $SD = 16.757$  could be lack of active participation in acquiring knowledge necessary to solve the scenario.

According to analysis of data from interviews, questionnaires, and marked activities the researcher is perceived to be effective if the students had developed the necessary skills, such as self-directed learning, critical thinking, literature researching, problem solving, and collaborative learning after the trials with RBTEA approach. Diagnosis and prognosis of the findings are indicated.

**Keywords:** water-recycling; chemistry; research-based teaching (RBTEA); locally available materials (LAMs); rubric assessment tool (RAT).

### **1.1 INTRODUCTION**

Chemistry is a body of knowledge and way of thinking, which enables students to understand what, happens around them. Roberts, (1983) opined that in order to challenge the status quo of school science, one needs a slogan to create networks of science educators dedicated to a renewed vision of how to achieve scientific literacy. Over the past two decades in several countries such the United States of America (USA), that slogan has been "SCIENCE TECHNOLOGY-SOCIETY" (STS). STS instruction aims to help students make

sense out of their everyday experiences, and does so in ways that support students' natural tendency to integrate their personal understandings of their social, technological, and natural environments. Scientists predict shortage of fresh water sources for human consumption from surface and ground water as early as 2015 in South Africa (Rencken, 2010). Therefore, recycling of water starting first at household level through water source re-use of borehole or municipal water will save water for South Africa.

Currently the Department of Water Affairs and Forestry (DWAF,2010) co-ordinates the South African Youth Water Prize Competition (SAYWP) by engaging students and educators on different educational projects where they identify water and sanitation related problems in their local environment, conduct researches, implement solutions and come up with recommendations. The 2020 Vision for Water Programme has been integrated with the Working for Water schools-based programme and is called the Water Education Programme (WEP) which has since been integrated into the school curriculum.

This study holistically discourses learning outcome 3 (LO3): The nature of science and its relationship to teaching, society and the environment (Department of Education, 2003:13-14). The Department of Basic Education prescribes through the new Curriculum Assessment and Policy Statement (CAPS) and the National Curriculum Statement (NCS) that all Physical Sciences students grade 10-12 undertake one research project task per year as part of their Continuous Assessment (CASS) to improve understanding of classroom chemistry, hence performance and achievement.

Literature research in developing countries is very rich on the use of materials from the local environment as substitutes for processed laboratory materials for chemistry experiments, but not much has been documented on the use of LAMs in chemistry research-based teaching. The major task is to assist teachers learn how to design and construct materials in line with students' enacted worldviews hence help them in making border crossing easier (Aikenhead and Jegede, 2000). Ekborg, (2003) noted with concern the inadequacies in teacher education programmes to use science to solve complex environmental issues due to lack of conceptual framework about science. In response, Obanya (1989) suggested that improvisation becomes an area of specialisation in teacher education and technology programmes.

According to Alonge (1979) countries like India, South Korea and Japan have made significant progress by teaching sciences using own materials. Another issue central to this study is the need for chemistry students in developing countries to start seeing chemistry as broad and everyday practical reality.

Seopa et al (2003), Rogan and Aldous (2005) highlighted lack of students' autonomy in science practical work in schools; and labelled it "cookbook approach." If students doing

research and practical investigations are to become wide spread in South Africa classrooms, teachers need to possess the necessary pedagogical skills and resources to guide and facilitate inquiry based learning through the Outcomes Based Education(OBE) teaching approach, (Onwu and Stoffels; 2005:80).

In a survey of science education in the United States conducted in 2000 by Horizon Inc. for the National Science Foundation (NSF) it was shown that only 12% of teachers indicated students were asked to design or implement their own investigation (Smith, Banilower, McMahon & Weiss, 2002:42). Science investigations continue to be presented in teacher-scripted worksheets where students follow directions to merely confirm textbooks answers (Trumbull, Scarano & Bonney, 2006:1718).

Therefore, as an instructional approach RBTEA approach using LAMs anchored in Problem-Based Learning (PBL) has high potential in promoting inquiry in science classroom (Baud & Feletti, 1991).However, the use of this approach is relatively new in developing countries and not much research has been done in the area of chemistry education. In this respect, this study is motivated specifically by an existing gap in literature, as there are no published or unpublished papers on chemistry RBTEA approach using LAMs and learning for grades 10-12 in Limpopo Province

The aim of this paper is to provide a clear link between the theoretical principles of constructivism and RBTEA approach in the development of Design and Technology (D&T), (Choksi et al, 2006) instruction manuals required to solve the water recycling invention case using LAMs.

## **1.2 THEORETICAL FRAMEWORK**

There is not a single way to conceptualize learning systems. The challenge is to understand and evaluate the worth of different perspectives and methods to guide the design of effective instruction for students.

*The questions driving the argument in this paper include: What do constructivist perspectives offer instructional design and practice in this invention case?*

According to Von Glaserfeld (1984), students construct understanding. Woolfolk (1993:485) described the constructivist view of the learning process as active; information may be imposed, but understanding cannot be. According to Brooks and Brooks (1993), a good problem is one that

- requires students to generate and test hypothesis.
- can be solved with inexpensive LAMs
- is realistically complex
- benefits from group effort

- is seen as relevant and interesting by students.

In addition, the constructivist perspective supports instruction that provide students with a collaborative situation in which they have both the means and the opportunity to construct 'new and situation ally-specific understandings by assembling prior knowledge from diverse sources', (Ertmer and Newby, 1993:63).

Vygotsky's (1986) theory of social constructivism, as opposed to Piaget's (1977) individualistic approach to constructivism embodies his belief that learning is directly related to social development (Rice & Wilson, 1999). In this respect, the author employed "productive" type of questioning (Chin, 2007:818), to the experimental groups, which invokes Vygotsky's notion of mediated learning in the zone of proximal development (ZPD).

Brook, Driver & Johnston (1989) observed that in formulating an investigative question, students need to have a good grasp of the notion of a variable. Therefore, during the stages of the investigations through "the need to know worksheet," the author supported them in ensuring that the question they posed was clear and investigable. Support at this initial phase is particularly important as identifying a question plays such a powerful role because it gives meaning and direction to what follows (Kuhn, 2007; Howes, Lim & Campos, 2009).

Brooks and Brooks (1993) conceive of a constructivist teacher as someone who will be a facilitator, responsible for guiding students to identify the key issues and to find ways to learn those areas in appropriate breadth and depth using a variety of materials. The researcher will be perceived to be effective in his study if the students had developed the necessary skills, such as self-directed learning, critical thinking, literature researching, problem solving, and collaborative learning after the trials with RBTEA approach. A related approach is anchored instruction in apprenticeship model described by Rogoff (1990:7) which considers children as apprentices who develop skills and understandings from participating with more skilled members of their society within the context of socio-cultural activity.

### **1.2.1 STATEMENT OF PROBLEM**

The poor performance of students in Physical Sciences at grade 12 in South Africa is a reflection of the failing education system in the instruction methods in schools. Practical work in the school science curriculum has formed the focus of curriculum reform initiatives, which have taken place worldwide (Gott & Duggan, 2007:271). However, schools in rural areas and most previously disadvantaged urban schools have a shortage of science apparatus (Sadler & Tai, 2001), and this is true in most Limpopo Province schools.

The problem of practical infrastructure in schools is a serious one, which is common to most schools in developing countries, and is the highlight subject of current researches. This

scenario calls for critical investigation on the effective teaching approaches using LAMs in classroom chemistry, hence demand these specific research questions:

1. Is there a statistically significant difference between students' performance learning about invention case of water-recycling device at household level using LAMs through RBTEA approach compared to conventional teaching approach?
2. What are the views or attitudes of educators and students regarding the use of LAMs in conducting chemistry research projects at school?
3. Do teachers integrate LAMs as concept in their teaching approaches in classroom chemistry in the absence or inadequate practical infrastructure?

### **1.2.2 HYPOTHESIS**

The null hypothesis,  $H_0$  related to question 1 was thus coined:

The developed RBTEA activities were not effective when used by students' groups inventing the water-recycling device using LAMs. Hence, there will be no significant difference in assessment for students' experimental groups, who were extra taught on the scenario integrating LAMs as a concept in classroom to the control groups who were not, but taught using conventional method.

## **1.3 RESEARCH METHOD**

### **1.3.1 Population and Sample**

Thus, participants were selected based on the potential they had for contributing to the project (Miles and Hubermann, 1984; Bogdan and Biklen, 1998). Four High schools in Vhembe District, Limpopo Province each providing a group of five students based on their record of high performance in their Continuous Assessment (CASS) tasks particularly in practical investigations and research projects and in end of year examination in chemistry in grade 10, and 1 chemistry teacher were purposively stratified according to rural and urban proximities. Two of the schools were then conveniently selected where there were assigned experimental groups, which are easily accessible, and the other control groups, which are relatively far apart.

These two groups are not comparable in terms of geographical areas but are within a minimum of 3km and maximum of 15km radius of each other and of the small shopping mall, the main business activity of this peri-urban village town. Transport access is easy; therefore, all the four schools have a mix of rural and peri-urban teachers and students making them comparable in terms of access to learning resources. Sample of secondary schools information is given below:

**Table 1.1: Statistics of sample schools**

Group	Status	School population	Grade 11 physical sciences classes	Grade 11 Physical Teachers	Average number of students per class in grade11
A:Experimental	Urban ,boarding	1500	2	3	65
B:Experimental	Day semi-urban	1700	2	4	75
C:Control	Boarding, rural	600	1	2	60
D:Control	Day rural-Control	900	1	2	70

The students' ages ranged from 16 to 17 years old. Group samples worked with mixed gender of at least two girls.

### **1.3.2 DESIGN**

This study constitutes an empirical inquiry that investigated invention case of the said device within real life context; therefore, the research approach is a mix of qualitative and quantitative methods. The study is guided by nonequivalent pre-test-post-test control groups design and is quasi-experimental in nature as it involves human subjects not randomly sampled due to constraints (Campbell and Stanley, 1963), hence best for field surveys. There is no perfect design but correct choice, use and evaluation validates it.

**Table 1.2: Nonequivalent pretest-posttest control groups design**

Groups	Pre-test	Treatment	Post-test
EG	T1 T2	X1	T1 T2
CG	T1 T2	X2	T1 T2

EG=Experimental group, using the RBTEA (X1).CG=Control group, using the conventional approach, (X2).T1=Research-based Test (RBT2), T2=Rubric Assessment Tool (RAT).Pre-Post-tests of EG are compared with those of CG by effective matching across groups since maturation selection effect was used that experimental groups develop faster than control groups.

### **1.3.3 Instruments**

Four instruments were used in this study: Research-Based Tests (RBT1; RBT2), Rubric Assessment Tool (RAT), questionnaires, and interviews. All the test items in RBT1 (pre-test) and RBT2 (Appendix RBT2) were reviewed by the four chemistry teachers in the four schools and they all agreed that the test sufficiently covered the content in grade 10 specifically Learning Outcome ( LO3) and proved reliable on Cronbach scale 0.75. Rubric Assessment Tool (Summary: Table 6 ) was peer reviewed by the four chemistry educators and was piloted at the four schools on students' formal chemistry research for Continuous Assessment (CASS), and found to have reliability of 0.85 on the Cronbach scale.

### **Questionnaires**

The questionnaire comprised of 25 questions in which students' opinions, interests and impressions of the use of LAMs in teaching chemistry especially research were investigated. 20 copies of the survey were distributed by the teachers 5 per each school and 18 were returned. 19 Likert type items on a 3-point scale, also included were five open-ended questions to give students opportunity to write their opinions 5-point scale with 5 items This response was possible because teachers handed in the surveys to students in class; they completed them and returned them the following day.

### **Interviews**

Oral interviews of 25 questions for teachers similar to questionnaires constructed by the researcher were administered to the four groups of students at their schools on different days after school hours. The teachers were also interviewed individually. The interview questions were semi-structured split into halves, short and clear and lasted for 30-40 minutes. The idea was to maintain consistency with questionnaires thus achieving results that are credible, transferable, dependable and confirmable through probing further and further. Thus, face-to-face interview is flexible and adaptable, hence useful when seeking in-depth information and perceptions (Babbie, 1993).

The following information was obtained through Interview schedule for teachers and students:

- teacher background: qualifications and teaching experience
- the teaching approaches on students' research projects using LAMs ,
- challenges experienced when teaching research using LAMs,
- whether the teachers make use of LAMs in practical demonstrations and activities during their lessons in related case like Water-Recycling at household level.

The interviews were audio taped and transcribed verbatim by the researcher .Interview results were then used to construct the items of diagnostic tools RBT1 RBT 2 and RAT.

### **1.3.4 Intervention**

Problem Case (Scenario)

A crucial aspect of this study is the actual design of the problem to be solved using RBTEA approach. In this study, a case of water-recycling at household level was (scenario) developed covering different aspects of application chemistry of water-recycling. In designing the scenario, the educational impact of the problem in terms of promoting curriculum and pedagogy and being a part of or close to real life situations and arousing students' attention were considered.

In Stage 1, the experimental students were presented with a problem case task (PCT) in class for discussion. In Stage 2, the students identified learning issues related to the problem case and organised them around three critical questions: a) What do you know? (b) What do you need to know? (c) How can you find out what you need to know? using a 'need-to-know' worksheet which served as "a central focus point for the unit and represented the continuing cycle of problem definition, information gathering, analysis and synthesis of information, and problem redefinition", In Stage 3, the students applied the scientific inquiry to answer their own questions. Some of the students used the science laboratory to carry out their investigations, some looked up information from print and electronic resources using both library research and the Internet, and others consulted expert professionals and teachers, In Stage 4, synthesis and analysis of data, the students reported on what they had done, and prepared a report for the presentation to the classroom, In Stage 5, each group gave a 5-10 min oral presentation on their problem case, (Gallagher et al., 1995, p, 136-146).The students also submitted a group report that documented the group's findings and details of the inquiry process as in PCT.

#### Grouping and stages of Implementation:

The researcher's direct actions of practice within participants in the groups was able to "soak" and "poke" students through productive questioning with the goal of improving performance particularly in the experimental groups (Dick, 2002). In the experimental groups, firstly students were informed about the scientific method and its processes, and went through five consecutive stages described above. In the control groups, students were not informed. Both the experimental groups and control groups were observed during implementation of RBTEA approach and activities by the researcher. The two groups spent equal time studying the unit. The researcher, taught the experimental groups A and B and control groups C and D. The lessons in experimental groups generally focussed on prepared worksheets and demonstrations of the scientific method of research designed to facilitate students' understanding of the problem case through practical sessions. In the control groups, control strategies involved conventional teaching approach, which was mainly dominated by the usual classroom lessons, in-class discussions and problem solving involving talk and chalk sessions without worksheets and practical sessions.

Intervention involved 16 teaching hours over eight weeks (2 hours per week). The, usual time allocated to the teaching and facilitating of the problem case as water-recycling at household level using LAMs in NCS is 11 weeks (1 school term) and in new CAPS it is 22 weeks. The first lesson was on Chemistry of water (concept) in order for the students to develop the conceptual framework in chemistry as regards the processes of water-recycling students. The experimental groups were completing activity sheets as they carried out the activities, but the control groups were not. The researcher spent longer time with the experimental groups guiding them as they revised and refined their ideas in the course of posing and testing a hypothesis on the invention of the said device; they were following a process that leads to deeper conceptual understanding. (Marzano, Pickering, & Pollock, 2001).

In the second lesson students were given Model Picture of water-recycling on the topic Water-recycling chemistry in which they were asked to identify and draw mind maps of the future water-recycling device using LAMs indicating the major purification stages hence, explain the chemistry behind each process stage.

In lesson, three, which was a double lesson the researcher, introduced students to The Scientific Method through pre-laboratory and pre-research chemistry-based lessons. In their quest to solve the problem case, the students also used the laboratory to investigate qualitatively the pH of samples of water and chemical impurities like carbonates, nitrates and nitrites.

Lessons were one-hour periods. After 6 months, the invention of the said device was completed, and after all the trials RAT, and the post-test, RBT2 were administered to both the experimental and control groups. Teachers supervised students' research project in both groups as participants were working with household and laboratory chemicals and as per requirements of the Ethical Committee clearance.

The completed activity sheets were marked and analysed using GraphPad InStat-3 statistical software (2012).

## **1.4 RESULTS AND DISCUSSIONS**

### **1.4.1 Unpaired t-test for RBT1: Combined Experimental groups A and B vs. Control Groups C and D.**

The RBT1 was administered to combined experimental groups A and B ( $\bar{X}$  =13.30; SD=2.21) and control groups C and D ( $\bar{X}$  =12.11; SD=0.78) before intervention. No statistically mean difference was found between the combined two groups. ( $t=1.626$ ,  $DF=18$ ,  $p>0.05$  i.e.  $p=0.0213$ ), indicating that students in the experimental and control groups were similar in respect of achievement in the pre-test RBT1.

**1.4.2 Linear Regression for Pre-test-post-test experimental groups A and B, statistical analysis:**

Number of points = 10

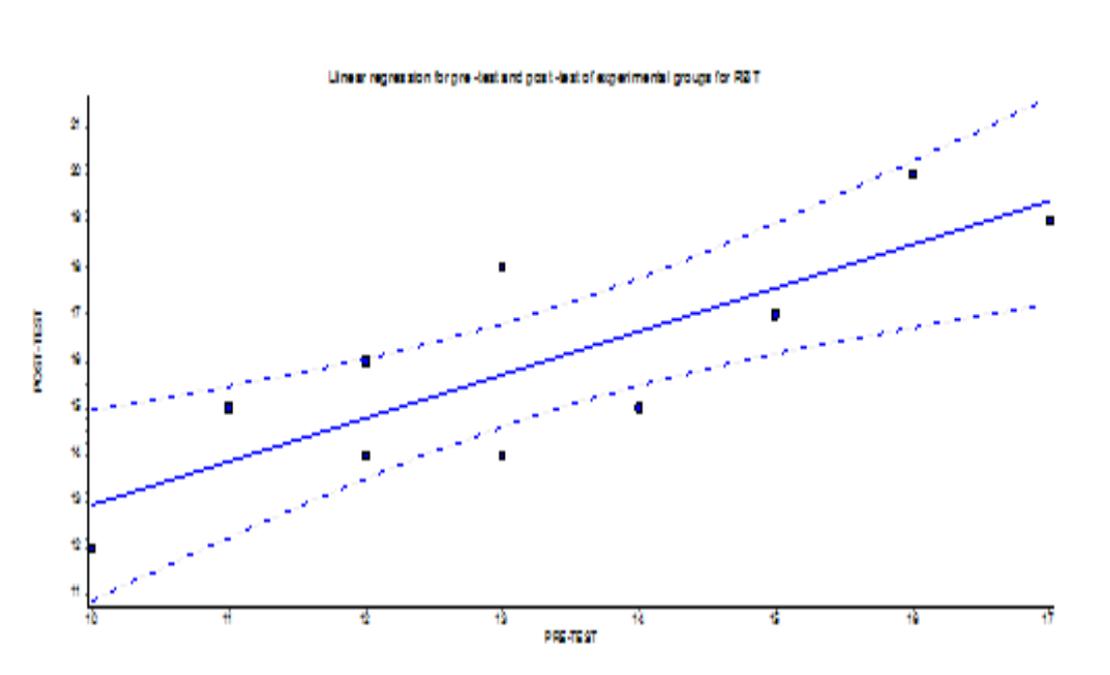
Correlation coefficient (r) = 0.8250.  $r^2 = 0.6807$  SD of residual from line(sy:x) = 1.495. Test: Is the slope significantly different from zero? P=0.0033, considered very significant difference in favour of post-test for experimental group. F = 17.053. This result was obtained from the following ANOVA Table 2.

**Table 2: Linear regression of pre-test-post-test of experimental groups. (ANOVA results)**

Source of Variation	Degrees of freedom	Sum of squares	Mean square
Linear regression (model)	1	38.118	38.118
Deviations: linearity(Residual)	8	17.882	2.235
Total	9	56.000	

Figure 1 below: Linear regression graph clearly shows that there is a significant difference within the mean of pre-test and post-test scores for experimental groups. Therefore, this confirms positive causal effects with RBTEA intervention in groups A and B as it increased difference between the control groups C and D. in worse direction.

**Figure 1: Linear regression graph for pre-test post experimental groups A and B**



**1.4.3 Linear Regression for Pre-test-post-test control groups C and D, statistical analysis:**

For the linear regression of pre-test and post-test for control groups there is no significant difference in mean between pre-test and post-test for control groups, hence the

conventional teaching material did not make a significant positive impact in terms of achievement. Correlation coefficient ( $r$ ) = -0.5423.  $r^2$  = 0.2941. SD =0.8660, residual from line. Test: Is the slope significantly different from zero? No,  $p$ = 0.1053, hence not significant since  $p > 0.05$ . This result was obtained from the following ANOVA Table 3:  $F = 3.333$ . Number of points =10

**Table 3: Linear regression of pre-test-post-test of control groups (ANOVA)**

Source of Variation	Degrees of freedom	Sum of squares	Mean square
Linear regression( model)	1	2.500	2.500
Deviations from linearity(Residual)	8	6.000	0.7500
<b>Total</b>	<b>9</b>	<b>8.500</b>	

#### 1.4.4 ANOVA multiple-comparisons of pairs of experimental groups within and between control groups for Post-Test (RBT2)

One-way Analysis of Variance (ANOVA)  $P < 0.0001$ , considered extremely significant. Variation among groups is significantly greater than expected by chance. Multiple Comparisons Test: Using  $MS = 1.994$ ,  $DF = 16$  from Intermediate calculations. ANOVA results. (see Table 4),  $N = 5$  for each group, and  $M_1 - M_2$ , if  $q > 4.046$  then the  $P < 0.05$  is statistically significant.

**Table 4: Multi Comparison Test (RBT2) of mean and SD among all groups: A, B, C, & D.**

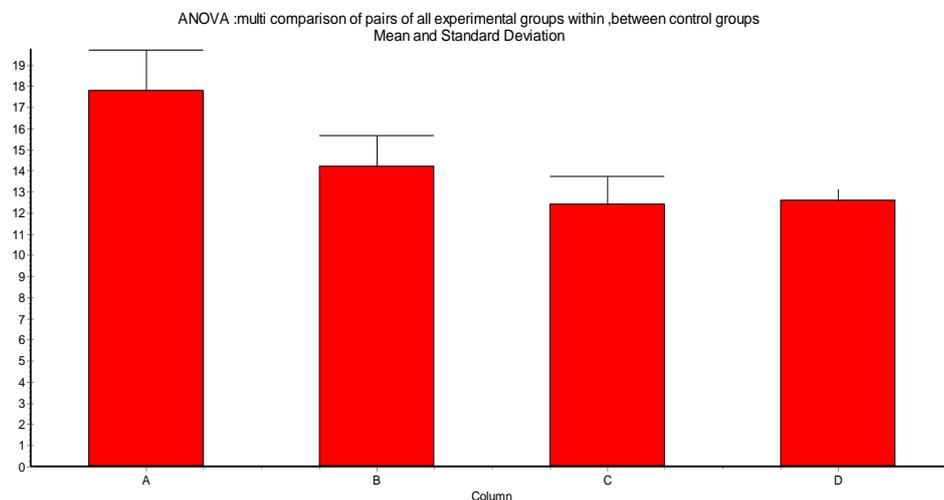
COL. title	A-Day, urban	B-Day, semi-urban	C-Day,Boading	D-Day, rural
Mean	17.8	14.2	12.4	12.6
Standard deviation (SD)	1.920	1.480	1.340	0.5500
Sample size (N)	5	5	5	5

**Table 5: ANOVA results from multi-comparisons test for RBT2 of group pairs.**

Comparison :Groups	Mean Difference	q	p	Value
A vs. B.	3.600	5.701	**	$P < 0.01$
A vs. C.	5.400	8.552	***	$P < 0.001$
A vs. D.	5.200	8.235	***	$P < 0.001$

<b>B vs. C.</b>	1.800	2.851	ns	P>0.05
<b>B vs. D.</b>	1.600	2.534	ns	P>0.05
<b>C vs. D.</b>	-0.2000	0.3167	ns	P>0.05

Figure2



#### 1.4.5 ANOVA multiple-comparisons of pairs of experimental groups within and between control groups for Rubric Assessment Tool (RAT)

Multiple Comparisons Test If  $t > 3.153$  then the  $P < 0.05$ . One-Way analysis of variance for the main and combined effects of RBTEA on students achievement showed new instruction is positive and significant at 0.05 level

Table 6: Summary of raw scores in percentages in RAT per chapters of invention write-up.

Skills Summarised/Chapters	Possible mark	A- mark	A- %	B- mark	B %	C- mark	C- %	D- mark	D %
1. Introduction: Background of study; problem statements; hypothesis.	24	16	67	16	67	11	49	8	33
2.Literature review/development/project focus on the problem case.	8	7	100	8	88	5	63	5	63
3.ResearchMethods: realisation/production of unit i.e. plan, design, and construction of device.	41	32	61	25	78	9	64	13	32

4. Discussion/Data Analysis: originality, functionality of unit.	12	6	58	7	50	2	17	2	17
5. Results and Conclusion: oral presentations, project write-up.	15	9	60	9	60	8	53	5	33
Total	100	70		65		35		33	

**Table 7: Multi Comparison Test (RAT) of mean and SD among all groups:A,B,C,& D**

Col. Title	A	B	C	D
Mean	69.2	68.6	49.2	35.6
Standard deviation(SD)	17.541	14.893	19.110	16.757
Sample size(N)	5	5	5	5

P <0.0001, considered extremely significant. Variance among groups means is significantly greater than expected by chance.

**Table 8: Group pairs Comparison: ANOVA of post-test (RAT) for all groups A, B, C, D.**

Comparison	Mean Difference	t	P	Value
A vs. B	0.6000	0.1113	Ns	P>0.05
A vs. C	20.000	3.711	*	P<0.05
A vs. D	33.600	6.235	***	P<0.001
B vs. C	19.400	3.600	*	P<0.05
B vs. D	33.000	6.124	***	P<0.001
C vs. D	13.600	2.524	Ns	P<0.005

For Intermediate calculations. ANOVA,  $F = 18.24 = MS_{\text{treatment}}/MS_{\text{residual}}$ . Assumption test: was the matching effective? This test uses a second value of F and a different P value=  $13.191 = (MS_{\text{individual}}/MS_{\text{residual}})$ . P = 0.0002, considered extremely significant. Effective matching (or blocking) results in significant variation among means. With this data, the matching appears to be effective.hence A vs. C; A vs. D; B vs. C; B vs. D show significant differences in mean at <0.05.

#### **1.4.6 Post-response: RAT: (RUBRIC) experimental and control groups (combined).Unpaired t test.**

Post-response: RAT: (RUBRIC) experimental and control groups (combined).Unpaired t test. Do the means of experimental groups A and B and control groups C and D combined differ significantly? Yes, the means differ very significantly not by chance but due to new instruction in favour of the experimental groups A and B. The two-tailed P = 0.0026, considered very significant.t = 3.498 with 18 degrees of freedom.95percentage CI=10. Mean

difference = -26.500 (Mean of control group minus mean of experimental group) at 95% CI Difference= -42.416 to-10.584.

From question 1 and the raised hypothesis results in sections 1.4.1-1.4.6 are discussed below:

- Linear regression for pre-test-post-test combined experimental groups A and B (see Table 2), ANOVA results of RBT2, N=10; SS=38.118; MS=38.118; DF=8, show significant difference within mean pre-test and post-test scores which is not by chance, but indicate the positive response of RBTEA intervention on the water chemistry concept and water-recycling leading to the invention and claim of the said device.
- Linear regression for pre-test-post-test combined control groups C and D show no significant difference in means (see Table 3), ANOVA results of RBT2, N=10;SS=2.500;MS=2.500;DF=8 .Therefore, the absence in RBTEA approach resulted in relatively low mean scores pointing out that the conventional approach of teaching the invention case of water-recycling at household level using LAMs is less effective. Therefore statistical regression increased differences between experimental group A and B vs. control groups C and D. (on the matched factor) at post-test level.
- Relatively high mean scores obtained from one-way ANOVA results for experimental groups A and B respectively: in RBT2:  $\bar{X} = 17.8$ ; SD=1.92 and  $\bar{X} = 14.2$ ; SD=1.48 and in RAT:  $\bar{X} = 69.2$ ; SD=17.541 and  $\bar{X} = 68.6$ ; SD=14,893 point out that students experienced a constructivist environment and they had the opportunity to develop inter-personal skills through RBTEA approach. The reason for poor performance in control groups C and D respectively in RBT2:  $\bar{X} = 12.4$ ; SD=1.340, and  $\bar{X} = 12.6$ , SD=0.5500 and in RAT:  $\bar{X} = 49.2$ , SD=19,110 and  $\bar{X} = 35.6$ ; SD=16.757 could be lack of active participation in acquiring knowledge necessary to solve the scenario (See Tables 4 and 7).
- ANOVA multiple-comparisons of pairs of experimental groups within and between control groups for Post-Test (RBT2) show that urban and semi-urban groups A and B respectively always outperform the rural groups C and D, at  $p < 0.05$  hence, stratification or geographical area has positive effect possibly due to access to learning resources like libraries, laboratories, textbooks, LAMs etc for groups A and B. The overall best group in terms of RBT2 scores is B, partly because it is urban with the said advantages (see Tables 4, 5 and Figure 2).
- ANOVA multiple-comparisons of experimental group pairs A and B within and between control group pairs C and D for RAT in the invention of the said device (see Tables 6,7 and 8).N =5,  $p < 0.05$ ; for A vs. C,A vs. D, B vs. C,B vs. D. mean is statistically

significant hence experimental groups A and B performed better in terms of realization of the said device using LAMs indicating that RBTEA approach had positive effect in improving performance. But for A vs. B,  $p > 0.05$ , there is no mean significant difference since all these were experimental groups and given that there was no variation at the beginning of the study, the two groups received relatively similar treatments which rendered their results comparable without significant mean statistical differences. Also C vs. D,  $p > 0.05$ , hence there is no mean statistical significance in these rural groups C and D in their relatively low scores in RAT in the invention of the said device partly due absence of RBTEA approach and lack of local resources in the rural areas.

- In addition the two tailed test (see section 1.4.6) , $p = 0.0026$ ,  $t = 3.498$ ,  $df = 18$  considered extremely significant not by chance but by innovative instruction using RBTEA approach is in favour of the combined experimental groups A and B (see section 1.4.6)

*Hence, the null hypothesis  $H_0$  is therefore duly rejected. And the alternative hypothesis  $H_1$  is therefore accepted that the RBTEA approach cause a significant difference in means in favour of experimental groups A and B exposed to the RBTEA approach compared to control groups C and D exposed to conventional teaching approach on the invention topic water-recycling at household level using LAMs*

It is argued that in a problem solving or inquiry learning environment students either attained slightly higher scores than students in a conventional approach or attained at least similar scores (Miller, 2003; Rideout et al., 2002). Results of this study also confirm this view. Although a statistically significant difference between the total means scores of RBTEA approach and conventional students were found, this was not a large difference (Table 2; 5).

However, these data indicate that RBTEA may be at least as effective an approach of teaching chemistry to students in conventional lessons' discussions and problem solving. Almost all case problems trials reported that students perceived their learning environments to be more positive than their counterparts in conventional programmes (Miller, 2003; Rideout et al., 2002; Soderberg & Price, 2003). The experimental groups mean scores point out that students experienced a constructivist environment and they had the opportunity to develop inter-personal skills through problem solving.

#### **1.4.7 From research question 2:**

Qualitative data was broken down into simpler and manageable units, according to Brown (1996), Duffee, and Aikenhead (1992), by matching students' views with those of teachers and placed into logical and meaningful categories, which generate themes and patterns. Seventeen of the eighteen students who participated in interviews and questionnaires stated that chemistry is useful, practical and applicable to life at home; one of them

believing that the subject is difficult, and *“valueless as what is taught in schools is not related to university courses and life.”*

They also believed that there is need to conserve nature especially water in these drought prone areas through invention of household recycling device using classroom chemistry and LAMs. Even if students acknowledged some similarities between processed laboratory materials and substitute LAMs, they were rather sceptical about the effective use of LAMs in chemistry experiments, but were very optimistic on their use in innovation researches such as in this scenario.

#### **1.4.8 From research question 3:**

50% of teachers and 85 % of students could not recognise the link between chemistry and LAMs due to their enacted views or culture and lack of teacher education component in the concept. Thus, generally except for teacher A of experimental group A, the findings reveal that the teachers were not integrating students' views and LAMs into their teaching of chemistry. Some students pointed out some teachers were not giving students chance to perform chemistry investigations because the teachers themselves *“were ignorant of research-based concepts.”* They argued that the teachers' excuses about lack of facilities were pointless since appropriate experiments could be performed using local resources, which were readily available and abundant. It also emerged that as teachers focused on *“covering the syllabus”* they failed to recognise local resources, further aggravating learning of science at school.

All schools have no laboratories but at least have some micro-science chemistry kits. Students reported that chemistry lessons though interesting *“were as usual chalk-talk-talk.”* On identifying the topics, they carried out chemistry investigations and research projects at school, 60% of the students were not aware alleging that they had no laboratory and had *“just done them without knowing.”* The study revealed that as the teachers confine themselves to textbooks they ignore experiences pupils bring from their community. On the use of LAMs in classroom chemistry by teachers students admitted that their teachers gave them real life examples and assignment which need use of LAMs. However, 80% of them reported that teachers abandoned practical work and opted for the conservative teaching approach in the absence of practical infrastructure at school. The teachers complained that the prescribed one practical experiment and research task per year was not representative of the curriculum and lacked depth of chemistry of inquiry associated with the use of LAMs.

Though the teachers agreed that they would improvise where possible they demanded that the Department of Education provide *“well equipped laboratories”* or else, there be no practical work and teaching goes on with the conventional method.

Romanowski (1998) noted that in the absence of appropriate and adequate practical infrastructure in some schools educators use rudimentary science apparatus that depend on their experiences to define, select and organize information to teach students. Bajah (1991), Gbamanja (1988), and Loko (1988) argued that teachers should be resourceful hence look for alternatives that help them carry on with their work. All the four teachers admitted that they had facilitated chemistry investigations at school, using LAMs and would love to see local resources incorporated as concept in chemistry curriculum taking into account the diverse nature of South African population.

#### **1.4.9 Researcher's action visits findings:**

Responses during action visits and presentations indicated that this was the first time they had encountered such an approach and they were motivated to study as they realised that they could do something themselves. The RBTEA strategy also helped students to realise that chemistry is a real part of the everyday life as quoted:

*"I am now an inventor scientist. I want to save water using LAMs and classroom chemistry in my community."*

In addition, this scenario helped students to learn working in groups as quoted below:

*"Working in groups helped us to get responsibility and ownership. Failure of the group is also my failure we had to push through discussions opportunities."*

Moreover, students stated their satisfaction with RBTEA strategy that it was an approach that they were expecting at a university. This could be seen from the following quote:

*"This is new and no ordinary learning .This is what we call science for life."*

### **1.5 CONCLUSION**

From the findings alluded above the following conclusions were reached:

- The use of RBTEA approach using LAMs has a significant effect of improving students' performance in chemistry and other sciences examinations with greater conceptual understanding and interest.
- Small group projects are interesting and positively influence students' motivation in chemistry research, as most students are able to recall material they learn in the classroom particularly when they are working with LAMs.
- Teachers should be innovative as they use LAMs in RBTEA approach in classroom chemistry grounded in the constructivist theory in order to reach Vygotsky's ZPD or transformative phase by engaging students with productive tasks and questions.
- In-minds-on and in-hands-on skills are requisites for a good performance in research work and problem solving.

#### **1.5.1 Recommendations**

In view of the said findings and conclusions, the following recommendations will help inform improvement in teaching and learning classroom chemistry using LAMs through RBTEA

approach. However, given the small sample size, caution is advised with respect to generalising the findings.

- The result of this study indicates that the RBTEA approach using LAMs may be at least as effective a method of teaching basic science concepts to prospective teachers in teacher training faculties as is conventional teaching in schools.
- The Department of Education should allocate fewer periods to science teachers or pay science teachers higher salaries in form of a laboratory and research allowances as this study has proved that the researcher spent longer time with the experimental groups guiding them solve the problem.
- Supply of science equipment must be accompanied by training on how to use that equipment and modules on how to improvise in the absence of practical infrastructure to carry out science investigations at school.
- Teachers should use pre-laboratory and pre-research sessions when teaching research-based chemistry which can be effective in increasing meaningful learning using LAMs. Therefore, science teachers must pass practical investigations, research projects and Laboratory management as part of teacher training education in order for them to appreciate and understand improvisation or use LAMs in classroom chemistry.
- There must be an intensive in-service training on the use of LAMs as concept and for improvisation specifically in chemistry, physics, life sciences, agriculture and geography research projects for students.
- A large sample involving schools from other provinces and possibly other developing countries would investigate the challenges teachers and students face when integrating LAMs as concept in research-based chemistry particularly in Design and Technology and quantify difficult aspects of the scientific method with respect to student achievement. This would need resources to train teachers to work with control and experimental groups.
- The use of LAMs when taught as a chemistry concept would be able to make inroads in the advancement of science and technology at international level in line with the current global expectations of creating a scientifically literate student capable of problem-solving, communication, and decision-making in everyday living. (American Association for the Advancement of Science, 1989, 1993; Goodnough, 2002; National Research Council, 1996)

## **1.6 REFERENCES**

- Aikenhead, G.S., & Jegede, O.J. (2000). Cross-cultural science education: a cognitive explanation of a cultural phenomenon. *Journal of Research in Science*, 36(3):269-287.
- Alonge, E.I. (1979). The use of locally available materials for school chemistry in Nigeria. PhD Dissertation represented to the Chemistry Education Sector of the University of East Anglia, Norwich England.

- American Association for the Advancement of science. (1993). Benchmarks for science literature: Project 2061. New York: Oxford University Press.
- American Association for the Advancement of Science. (1989). Science for all Americans: Project 2061. New York: Oxford University Press.
- Babbie, E. (1993). The practice of social research. Bellman, California: Wadsworth Publishing Co.
- Bajah, S.T. (1991). Improvisation in technological development: Implications for technical teacher education. Lecturer presented at the University of Lagos, Akoka, and Lagos, Nigeria.
- Baud, D., & Feletti, G. (Eds.) (1991). *The challenge of problem-based learning*. New York: St. Martin's.
- Bogdan R.C., & Biklen S.K. (1998). Qualitative research in education: an introduction to theory and methods. (2nd ed.) Boston, MA: Allyn and Bacon, p 6-130.
- Brook A., Driver R., & Johnston K. (1989). Learning process in science: a classroom perspective. In: Wellington J (4th ed.). *Skills and processes in science education: A critical analysis*. London: Routledge.
- Brooks, J. G., and Brooks, M. G. (1993). In search of understanding: the case for constructivist classrooms, Alexandria, VA: Society for Curriculum Development.
- Brown, D.C. (1996). Why ask why: patterns and themes of causal attribution in the. *Journal of Teacher Education* 33(4):47-65.
- Campbell, D.T. and Stanley J.C. (1963). Experimental and quasi-experimental designs for research on teaching, Handbook on teaching, McNally College Publishing Company , Chicago.
- Chin, C. ( 2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching*, 44:815-843.
- Choksi, B., Chunawala, S., & Natarajan, C. (2006). Technology as a school subject in the Indian context. In K. Volk (Ed.), *Articulating technology education in a global community*. Conference proceedings of the international conference on technology education in the Asia Pacific Region (pp. 280-290). The Hong Kong Polytechnic University, Hong Kong. p 274-284.
- Department of Education. (2003). National Curriculum Statement 10-12. General Policy: Physical Sciences. Pretoria: Government Printer.p13-14.
- Department of Water Affairs, (2010).South African Youth Water Prize (SAYWP) Water Education Programme .Pretoria: Government Printer.
- Dick, B. (2002). *Action research: Action and research* Accessed on Feb 3, 2007
- Duffee, L., & Aikenhead G.S. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education* 76(5):493-506.
- Ekborg, M. (2003).How students use scientific conceptions to discuss a complex environmental issue. *Journal of Biology Education*.37 (3), 126-132.

- Ertmer, P.A., & Newby, T. J. (1993). Behaviourism, cognitivism, and constructivism: comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 6 (4), 50-72.
- Gallagher, S, A., Stepien, W. j., Sher, B. T., & Workman, D. (1995). Implementing problem-based learning in science classroom, *School Science and Mathematics*, 95(3), 136-146,
- Gbamanja, S.P.T. (1988).Essentials of curriculum and instruction: Theory and practice. Port Harcourt; University of Port Harcourt.
- Goodnough, K. (2002, April).Teacher developing through collaborative inquiry: Primary teachers enhance their professional knowledge for science teaching and learning. Paper presented at the National Association for Research in Science Teaching, New Orleans, April 2002.
- Gott, R., & Duggan, S. (2007). A framework for practical work in science and scientific literacy through argumentation. *Research in Science & Technological Education*, 25:271-291.
- Howes, E.V., Lim, M., & Campos, J. (2009). Journeys into inquiry-based elementary science: Literacy practices, questioning, and empirical study. *Science Education*, 93:189-217.
- Kuhn, D.( 2007). Reasoning about multiple variables: Control of variables is not the only challenge. *Science Education*, 91:710-726.
- Loko, A.S. (1988).Designing some improvised equipment for chemistry teaching in senior secondary school. Unpublished M.E.D.thesis. University of Lagos, Lagos Nigeria.
- Marzano, R.J., Pickering, D.J., & Pollock, J.E. (2001). Classroom instruction that works Research-based strategies for increasing student achievement. Alexandria, VA: Association for Supervision and Curriculum Development.
- Miles, M.B., & Hubermann, A.M. (1984). Qualitative data analysis, an expanded source book. (2nd ed.) Thousand Oaks: Sage, p 40-43.
- Miller, S. K. (2003). A comparison of student outcomes following problem-based learning: Instruction versus traditional lecture learning in a graduate pharmacology course, *Journal of American Academy of Nurse Practitioners*, 15(12), 550-556.
- National Research Council. (1996).National Science education standards. Washington, DC: National Academy Press.
- Obanya, P. (1989).Going beyond the educational reform document. *Prospects*, 19(3), 333-7.
- Onwu, G., & Stoffels, N. (2005). Instructional functions in large, under-resourced science classes: perspectives of South African teachers. *Perspectives in Education*, 23:79-91.
- Piaget J. (1977).The Group of Consciousness: Action and concept in the young child London: Routledge and Kegan.
- Rencken, G. 2010. South Africa: Shortage of fresh water supplies looming. *Engineering news*. Westerhof.
- Rice, M. L., & Wilson, E. K. (1999). How technology aids constructivism in the social studies classroom,<http://global.umi.com/pqdweb>.

- Rideout, E., England-Oxford, V., Brown, B., Fothergill-Bourbonnais, F., Ingram, C., Benson, G., et al. (2002). A comparison of problem-based and conventional curricula in nursing education. *Advances in Health Sciences Education*, 7, 3-7.
- Roberts, A. T. (1983). Influence of science teachers' ratings on their academic progress. Brock University: Ontario Canada.
- Rogan, J.M., & Aldous, C. (2005). Relationships between the constructs of a theory of curriculum implementation. *Journal of Research in Science Teaching*, 42:313-336.
- Rogoff, B. (1990). Apprenticeship in thinking. New York: Oxford University Press
- Romanowski, M.H. (1998) Teacher's lives and beliefs: influences that shape the teaching of U.S.history. *Mid-Western Educational Researcher* 11(2):2-8.
- Sadler, P. M., & Tai, R. H. (2001). Success in Introductory college physics: The role of high school preparation. *Science Education*, 85(2), 111-136.
- Seopa, M.A., Laugsch, R.C., Aldridge, J.M., & Fraser, B.J. (2003). Development of an instrument to monitor the success of outcomes-based learning environments in science in South Africa. Paper presented at the Third International Conference on Science, Mathematics and Technology Education, East London, South Africa.
- Smith, P.S., Banilower, E.R., McMahon, K.C., & Weiss, I.R. (2002). *The national survey of science and mathematics education: Trends from 1977 to 2000*. Chapel Hill: Horizon Research.
- Soderberg, P., & Price, F. (2003). An examination of problem-based teaching and learning in population genetics and evolution using EVOLVE a computer simulation. *International Journal of Science Education*, 25(1), 35-55.
- Trumbull, D.J., Scarano, G., & Bonney, R. (2006). Relations Among Two Teachers' Practices and Beliefs, Conceptualizations of the Nature of Science, and their Implementation of Student Independent Inquiry Projects. *International Journal of Science Education*, 28:1717-1750
- Von Glaserfeld, E. (1984). Radical constructivism. In P. Watzlawick (Ed.) *The invented reality*, Cambridge: Harvard University Press, 17-40.
- Vygotsky, L. S. (1986). *Language and thought*, Cambridge, Mass.: MIT Press.
- Woolfolk, A. E. (1993). *Educational psychology*, Bosten: Allyn and Bacon.

## **1.7 APPENDIX: RBT2**

### **Water Chemistry and Recycling: Post-Test.**

1. Chlorine is a reactive halogen element found in-group 17. Chlorine reacts with other elements forming a stable covalent bond by; A, losing electrons. B, sharing electrons. C, I do not know
2. Carbon is one of the filters used in the treatment of water from source or grey water for re-use. Carbon is in-group 4, is also a metalloid therefore as a filter can be used to: A, Remove chemical impurities e.g.  $Mg^{2+}$  and  $Ca^{2+}$ . B, Remove physical impurities e.g.

- big stones, dead animals etc. C, Deactivates pathogens (disease causing bacteria and virus). D, Remove chemical impurities and pathogens. E, Remove A, B and C above. E, I do not know
3. Water is a weak electrolyte, and behaves as both acid and base at room temperature, therefore water is said to be A, Amphoteric. B, Conjugate acid-base. C, Bronsted- Lowry acid. D, All of them A, B and C. E, None of them A, B and C. F, I do not know.
  4. Hard water usually lathers or forms scum with soapy water .Which two major ions are responsible for the hardness of water? A,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  . B,  $\text{Zn}^{2+}$  and  $\text{Fe}^{2+}$ . C,  $\text{Na}^+$  and  $\text{Cl}^-$  .D, I do not know.
  5. Disinfection of water with chlorine will take place optimally when pH is between 5.5 and 7. In the school laboratory acidity of water samples would be tested by: A, Tasting bitterness or sourness, Using universal indicator solution or litmus paper solution. C, All of the above. D, I do not know
  6. Water from source can contain impurities of carbonates, nitrates, nitrites  
Choose any one of the impurities above and explain how you would go about testing it in the laboratory or at school or I do not know.
  7. What do the phrase “recycling of grey water” mean?
  8. a) Suggest the meaning of term “physical filtration” as shown on the model diagram of water recycling.  
b) Which LAMs would you use for this process? Support your choice of local material with chemistry related reasons.
  9. a) Which LAMs would you use in “chlorination chamber” of water-recycling) Show how the acid responsible for killing pathogens is formed in this chamber.
  10. State ONE organic impurity in grey water hence discussed its chemical removal.